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INTEGRATED MANAGEMENT OF SCLEROTINIA AND BLACKLEG:

A NECESSITY FOR INTENSIVE CANOLA PRODUCTION IN E. CENTRAL

SASKATCHEWAN AND A REALISTIC OBJECTIVE

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1. ABSTRACT

Research on sclerotinia has focussed on refining petal testing as a method of disease forecasting and integrating it with chemical control. The effects on disease incidence of diurnal and long-term fluctuations in petal infestation with spores have been studied. The feasibility of growers setting up petal tests themselves was demonstrated. Half-dose fungicide applications at late bloom give good control of sclerotinia under some conditions. Initial promise shown by foliar fungicides for controlling blackleg was not subsequently realized. Attention has switched to a fungicide used as a fertilizer coating or seed treatment. Studies on mechanisms of plant infection and symptom expression may help explain why fungicidal control is difficult.

2. SUMMARY

SCLEROTINIA. During the three years of this study we continued to expand our data base on the relationship between percentage infestation of canola petals with Sclerotinia spores and disease incidence. This relationship is used as a forecasting tool for sclerotinia stem rot. Farmers were invited to participate by providing petal samples from the Melfort, Shellbrook, Meadow Lake and Outlook areas. In other studies we demonstrated that by sampling 40 petals from 5-6 sites in a field, percentage petal infestation could be measured with an accuracy of  $\pm 5\%$ , 19 times out of 20. The isolation medium which is used to test petals was modified in 1986 to allow identification of Sclerotinia (ie. reading the test results) after 3 1/2 days, instead of the previous 5 days. It was demonstrated in a study near Melfort in 1987 that farmers could set up their own petal tests as effectively as trained technicians. Thus, we have gradually moved towards making petal testing a practical method of assessing disease risk, which farmers will be able to use to decide whether to spray canola crops with a fungicide. Some fine-tuning of this system is still necessary and experiments have already been conducted on the effects that diurnal and long-term fluctuations in petal infestation and crop density have on disease incidence. Experiments in 1987 and 1988 suggest that diurnal variations in petal infestation and changes due to the onset of rain seldom exceed 30% and, therefore, are relatively unimportant for accurate forecasting. However, much greater changes in percentage infestation over the entire bloom period occurred in the same years. These represented changes from very low to high disease risk in the long term.

In work on chemical control late bloom application of a fungicide at the full or half rate has been studied. This can give adequate control when petal infestation does not indicate moderate disease risk until full bloom or later. Several new fungicides and formulations have been shown to be equally effective as the standard Benlate and Rovral when applied at the usual early bloom period. Half-dose fungicide applications have consistently been shown to give good control when disease pressure is low. The most effective control is achieved by splitting the full dose in two, applied about a week apart. Thus, the opportunity exists for growers to integrate disease forecasting with chemical control and time fungicide applications to coincide with high disease risk.

Finally, in studies in 1987 and 1988 on application technology, there has been good evidence that combinations of nozzle type and pressure that produce small spray droplets give optimum control. With such manipulation effective control may be possible with fungicide doses and volumes of carrier fluid much less than growers normally use. This would have great economic significance, but further tests under high disease pressure are necessary.

BLACKLEG. Field tests from 1986 to 1988 with foliar applications of several fungicides, in particular Rovral, Sportak, Impact, and Tilt, have given very disappointing results. Although significant reductions in disease severity have occurred, they have never been sufficient to be of economic interest. This applied both with the highly susceptible cultivar Westar and other cultivars which are more resistant. Because of these poor results, attention has switched to the possible use of flutriafol as a seed treatment or fertilizer coating. In an experiment in 1988 reductions of disease close to 30% were achieved with such treatments in a moderately resistant cultivar. Plant material collected from the test plots was analyzed for flutriafol residues and maximum uptake appeared to have occurred from flutriafol-coated 11/51/0. Further work with this fungicide is warranted. Even as Westar is replaced by more resistant cultivars that have recently been registered there will still be a need for chemical control.

Studies on the epidemiology of blackleg were initiated in 1988, with particular attention being paid to (a) the spread of the blackleg fungus from infected leaves through the leaf stalk into the stem and (b) latent (i.e. symptomless) infection of leaves and stems. There was a difference among cultivars of different resistance to blackleg in rate of spread in the leaf stalk and in the extent to which latent stem infections apparently disappeared towards the end of the summer. These results, if confirmed, will be potentially useful to plant breeders. A surprising finding was the very high incidence of latent stem infection in all cultivars tested. This suggests that the incidence of blackleg may be more a function of conditions that allow symptom development in plants with latent infection than of conditions that lead to initial infection. This, too could be important to plant breeders. Moreover the incidence of latent infection could account for the poor results achieved with foliar fungicide application.

## ABSTRACT

Research on sclerotinia has focussed on refining petal testing as a method of disease forecasting and integrating it with chemical control. The effects on disease incidence of diurnal and long-term fluctuations in petal infestation with spores and of crop density have been studied. The feasibility of growers setting up petal tests themselves was demonstrated. Full and half-dose fungicide applications at late bloom give good control of sclerotinia under conditions where inoculum was not abundant in the crop until full or late bloom. Promise shown by foliar fungicides for controlling blackleg was not subsequently realized. Significant, but non-economic reductions in disease were achieved by spraying with products such as Sportak, Tilt, Rovral and Impact. Attention has switched to using flutriafol as a fertilizer coating or seed treatment. Studies on mechanisms of plant infection, spread within the plant and symptom expression may help explain why fungicidal control is difficult. Data collected from disease nurseries on the relative susceptibility to blackleg of different canola cultivars and breeding lines have been used to support the registration of new cultivars.

BACKGROUND AND OBJECTIVES

This project grew out of the fusion of several observations and circumstances related to canola diseases in Saskatchewan. In the case of sclerotinia stem rot caused by Sclerotinia sclerotiorum, highly effective methods of control by foliar application of fungicides were available to growers by the early 1980s. However, the erratic occurrence of the disease coupled with high fungicide costs and frequently low canola prices made systematic crop spraying uneconomical, not to mention environmentally undesirable. There was clearly a need for a satisfactory method of disease forecasting which would enable growers to apply a fungicide only when disease risk was high and perhaps to adjust the timing and dose according to variations in risk. Work had been conducted by Morrall and co-workers from 1983-85 on the relationship of inoculum of Sclerotinia on plant surfaces to disease incidence. This indicated that disease forecasting based on testing the frequency of petal infestation with spores of Sclerotinia might be a considerable improvement over traditional methods. Thus, a major objective of the present work was to generate a larger data base on using petal testing for disease forecasting. Included in this goal was trying to fine-tune the petal testing system by studying diurnal and long-term fluctuations in petal infestation, as well as the influence of weather conditions and crop density on the relationship between petal infestation and disease incidence. These factors are important because they potentially affect the timing and frequency of petal testing and the adjustments for variable environmental factors necessary for accurate forecasting. A final objective of work on forecasting was to investigate whether the petal test could be conducted by growers themselves rather than by trained lab technicians.

Closely related to improved disease forecasting was work on fungicidal control of sclerotinia. Previous studies had suggested considerable potential for control with half doses and split doses of



fungicide. The present work was designed to confirm this finding and to test the efficacy of fungicide application at late bloom (as opposed to the previously recommended early-full bloom). It was believed that late bloom application might be effective under conditions where the appearance of inoculum in the crop was delayed by dry weather. Reduced, as well as recommended, fungicide doses were tested. When the appearance of inoculum was delayed, disease incidence would be expected to be lower and a reduced fungicide dose might provide the most economical control. Finally, studies were done to test the efficacy of control when fungicides were sprayed with different nozzle types, in different volumes of carrier fluid and with the boom at different heights above the crop canopy. These were undertaken in direct response to inquiries from growers about how to optimize their fungicide applications; it was evident that until 1985 fungicide spraying had followed a "hit or miss" approach. The studies of spraying technology that resulted included investigations of low fungicide dose and low volume applications.

In the work described below it is evident that many of the original objectives on sclerotinia have been wholly or partially achieved. However, a serious problem with dry weather in N.E. Saskatchewan in the summers of 1986, 1987 and 1988 has limited the success of the work. A number of our findings will remain tentative until we experience a year which favors high levels of disease. This would give us confidence that our conclusions hold up under more rigorous testing conditions.

In the case of work on blackleg disease caused by Leptosphaeria maculans, there were two major objectives: (a) better control through crop rotation and resistant cultivars, and (b) testing promising fungicides against blackleg in plots and on a commercial scale. The situation in 1985 was that the monoculture of Brassica napus cv. Westar in Saskatchewan was being devastated in many areas by blackleg. Growers were switching to older cultivars or to B. campestris or going out of canola production because of the disease and their perception that Westar was more susceptible than other cultivars. Yet the data available did not show unequivocally a significant difference between Westar and other cultivars. This was believed to be partly because the data had been collected mostly under conditions of low disease pressure. In the present study it was proposed to establish nurseries to evaluate blackleg reactions under heavy disease pressure, similar to the situation faced by many growers. Comparative data under heavy disease pressure have concurrently been gathered by other workers, thereby rectifying the lack of suitable information of a few years ago. The proposal to test promising fungicides against blackleg was based on the knowledge that even with the eventual registration of canola cultivars with more resistance to blackleg, additional control measures would be necessary. Tests in 1985 had suggested some potential for two foliar fungicides. Over the three years of the project the "promise" or "potential" has switched to a soil-incorporated fungicide.

#### EXPERIMENTAL METHODS

##### FORECASTING SCLEROTINIA BASED ON PETAL INFESTATION Large scale studies

In 1986 and 1987 brochures were mailed to growers in the Melfort area encouraging them to collect petal samples from their canola crops and take

them to our lab at the Melfort Research Station for testing. This was as a continuation of a large-scale pilot project initiated in 1985. In both years dry weather and low canola prices diminished grower interest in the project and the response was poor. As a consequence samples were also obtained in 1986 from crops in the Shellbrook and Meadow Lake areas through the assistance of local ag. reps. About 150 fields were sampled in total, stretching from Makwa to Carrot River. A very small number of samples were provided by growers in 1987 and all others used in the project were collected by a summer student as part of another study (see below). In 1988 dry weather again curtailed the project at Melfort and work was conducted at Meadow Lake and Outlook instead. A small number of samples were collected by growers but the majority were taken by research personnel as part of other experiments described below.

Crops were normally sampled at four or five sites in the field by picking the tops off 10-12 inflorescences and putting them in clean plastic bags. Forty petals were picked from the flowers from each site and plated, four to a petri plate, on potato dextrose agar containing antibiotics. After 3 1/2-4 days incubation at room temperature the percentage of petals infested with Sclerotinia (PPI) was recorded for each site. In August shortly before swathing, each field in which petal samples had been taken was inspected. Percentage disease incidence (DI) was determined by counting the number of diseased plants in a sample of 200 at each sampling site.

#### Study on adequate sample sizes

In 1986 petal samples were collected and PPI tested, as described above, on an intensive basis in two fields at Melfort and one at Meadow Lake. This was to complete a study initiated in 1985 on the extent of sampling necessary to make reliable estimates of PPI in fields. In two of the fields, samples were collected at 25 sites and in one at 10 sites. Forty petals were tested per site. In the same fields DI was assessed at each sampling site in August as described above and the data were eventually used to calculate the amount of sampling necessary to make reliable estimates of DI in fields.

#### Modification of Isolation Medium

Up to and including 1985, PPI was tested by plating petals on potato dextrose agar containing rose bengal and streptomycin to inhibit contaminating bacteria. Sclerotinia sclerotiorum was identified in the isolation plates after 5 days incubation. In 1986 laboratory experiments were done to modify the isolation medium to allow more rapid identification of Sclerotinia, thereby speeding up the process of petal testing. A wide range of antibiotics were screened initially, followed by testing a range of concentrations of those antibiotics which did not inhibit the growth of Sclerotinia. The tests were done mainly with canola petals which had been artificially infested with Sclerotinia by spraying with an ascospore suspension and artificially contaminated with bacteria by spraying with a soil suspension. The goal was to find an antibiotic combination which was not inhibitory to Sclerotinia but which controlled a broad spectrum of bacteria.

### Feasibility of do-it-yourself petal testing

In 1987 a project was done in the Melfort area to begin developing a petal test kit that growers could use themselves to determine PPI and forecast disease risk. A select group of growers were approached and eventually 29 participated in the project. Growers were given test kits containing petri dishes, disinfectant, forceps, etc. which enabled them to set up petal tests at home. Instructions on how to collect the petals and set the test up were provided in both written form and as a video, if a grower wished. When the grower actually set the test up, it was done independently at home, without additional coaching. However, within one hour of the grower collecting petals, duplicate samples were collected at marked sites in the same field by a trained technician and processed in a laboratory. Four days later the sets of petri dishes prepared by the grower and the technician were compared with respect to PPI, contaminants which made them unreadable, and other characteristics. Later in the summer each grower who participated was asked to fill out a questionnaire and respond to questions about his experience. From the answers it was possible to prepare profiles of the age and educational background of the growers and a list of technical problems encountered.

### Fine-tuning the forecasting system

Results from the studies in 1986 suggested the need for some refinement of petal testing as a forecasting technique; until then the concept was to conduct a single test at early bloom. Thus, a result would be available during full bloom at the latest, when spraying for control was known to still be feasible. However in a few fields in 1986 low PPI values were recorded at early bloom, yet considerable disease developed later. It was decided to conduct experiments to determine if this phenomenon was due to the influx of inoculum after early bloom or to inaccurate estimation of PPI because petals were sampled under adverse environmental conditions. Accordingly, in 1987 and 1988 PPI was monitored in a number of crops throughout the flowering period by repeated petal sampling at marked sites. In some cases petals were collected every few days to follow long-term changes and relate them to DI at the end of the season. In other cases petals were collected several times per day for brief periods and careful note was made of the weather conditions before and during sampling. This was to determine if there were diurnal fluctuations in PPI or if certain weather conditions influenced PPI, e.g. whether rain might wash spores of *Sclerotinia* from petals. In 1987 8 fields were monitored in the Melfort area and in 1988 29 fields were monitored in the Meadow Lake area. In several of the fields where fluctuations in PPI were monitored, microloggers were used to record macro and microenvironmental data such as temperature, time and amount of rainfall, relative humidity, and leaf wetness.

Another aspect of fine-tuning that was studied was the influence of crop density on the relationship between PPI and DI. In 1986 and 1987 qualitative assessments of crops in which petal samples were collected for forecasting had suggested that DI is higher per unit of PPI in dense crops. Therefore in 1988 more critical studies were attempted. Replicated plots were seeded at Melfort (Global and Tribute) and Saskatoon (Tobin) using different seeding rates. Sclerotia were incorporated into the soil between the plots to serve as inoculum. The intention was to thin the plants at the



rosette stage to establish different canopy densities, monitor PPI during flowering and measure canopy density and DI at the end of the summer. Another approach was to quantify crop density in the 29 fields at Meadow Lake in which PPI was monitored. After flowering had finished, measurements were made at each sampling site of plant height, number of plants per m<sup>2</sup>, mean stem thickness and % transmission of incident light through the crop canopy to the soil surface.

#### CHEMICAL CONTROL OF SCLEROTINIA Half-dose and split applications

In 1986 plot tests were established at Meadow Lake in two fields to compare the efficacy of half the recommended doses of three fungicides, Benlate, Rovral and Ronilan, on two dates of application, one at early and one at full bloom. In addition, applications of the recommended dose split between the two application dates were tested, including all possible combinations of any two of the fungicides. With appropriate checks, a total of 16 treatments were included in the test with four replications. This experiment was repeated in a single field at Gronlid in 1987. Shortly before swathing in each field, DI was assessed in each plot by counting the number of infected plants in a sample of 200. This work was done in collaboration with Dr. P.R. Verma, Agriculture Canada Research Station.

#### Late bloom fungicide application

In 1987 experiments were set up at Saskatoon (irrigated) and Canwood in which the efficacy of late bloom application of Benlate was tested when inoculum was introduced into the crop at early, full or late bloom. The inoculum consisted of a suspension of ascospores and/or mycelial fragments of *Sclerotinia sclerotiorum*, sprayed on the plants with a backpack sprayer. Benlate was tested at the recommended and at half the recommended dose, in a fully factorial, split-plot experiment with five replicates. The test at Saskatoon was later abandoned because no disease developed, despite inoculation and regular irrigation. In the test at Canwood DI was assessed in each plot in August by the method described above.

Tests were also established in 1987 in three commercial fields in N.E. Saskatchewan. On the basis of petal testing and of searching for apothecia, fields were chosen in which inoculum of *Sclerotinia* was first abundant at early, full or late bloom, respectively. At late bloom Benlate was applied at the recommended rate to 12 plots paired with 12 check plots. In mid-August DI was assessed in each plot as described above.

In 1988 plots were established in a total of 10 fields at Meadow Lake. These were chosen by monitoring PPI every few days from early bloom onwards in about 30 fields. Fields were selected in which PPI reached a moderate level for the first time at early, full or late bloom, respectively. In several fields in each group a test was established that was identical to those in N.E. Saskatchewan in 1987. In addition, a more elaborate test was put in several fields in which PPI reached moderate levels only at late bloom. This consisted of a factorial experiment with 2 spray nozzle types (intended to give small and large spray droplets, respectively) and four doses of Benlate: 0 (check); 0.125 kg a.i./ha (25% of recommended rate); 0.250 kg a.i./ha; and 0.5 kg a.i./ha. Disease was

evaluated in tests of both types in August by measuring DI as described above.

### Application technology

This work was initiated in 1987 by our contracting the services of Rogers Engineering Ltd. of Saskatoon and was continued in 1988 by Rogers Ltd. obtaining its own ADF grant and expanding the study. Our own direct input consisted of providing manpower and expertise for selection of test sites and carrying out disease assessments. Rogers Ltd. provides the engineering expertise and tractor-mounted spray equipment and does the spraying. The purpose of the work is to determine the effect of variations in nozzle type and spray pressures, volume of carrier fluid, and height of the spray boom on the efficacy of control of sclerotinia with fungicides.

In 1987 a suitable commercial field was located near Gronlid and plots were established in which the following variables were studied: Fungicide (Benlate vs. Rovral); Dose (Full, 1/2 and 1/4 the recommended amount); nozzle type (80015 vs. 11001); volume of carrier fluid (50 vs. 100 l/ha); and boom height above the crop canopy (10, 30 and 60 cm). A 3-replicate split-plot design was used, with Benlate vs. Rovral as the subplot factor. The main plot factors were not fully factorial because of limitations of time and space. Spraying was done on July 8 and 9 when the crop was at early bloom. In late August DI was assessed in each plot by the method described above.

In 1988 two experiments were done near Meadow Lake in a commercial field, selected because of high disease potential. In one experiment Rovral was used and the treatments were selected from among those tested in 1987; the objective was to confirm the previous results. In the other experiment Benlate was used and the following variables were studied: Dose (Full, 1/2 and 1/4 the recommended amount); combinations of nozzle type and spray pressure (80015 + 297 kPa; 800067 + 297 kPa; 800040 + 414 kPa; 1100025 + 552 kPa; 800017 + 552 kPa); volume of carrier fluid (10, 15, 27, 50 and 105 l/ha). In both experiments the treatments were in a non-factorial combination and were replicated three times. Spraying was done at early bloom on July 7 or July 8. In late August DI was assessed in each plot by the method described above.

### Testing New Products

In each of 1986, 1987 and 1988 experiments were set up in commercial fields of canola to test the efficacy of new fungicides and new formulations of fungicides to control sclerotinia stem rot. Such work is done in collaboration with Dr. P.R. Verma, Agriculture Canada, Saskatoon. Our component is mainly in selecting suitable test sites by scouting fields and petal testing and in helping in the assessment of DI. The experiments are invariably done in small plots sprayed with a hand-held precision sprayer. The same test is repeated at two locations using a randomized complete block design. Fungicides and formulations vary from year to year but in each year new products of interest to industry and growers are compared with the two registered products, Benlate and Rovral, as well as a non-sprayed check.

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INTEGRATED CONTROL OF BLACKLEG  
Foliar fungicide applications

In 1986 plots were established at Saskatoon under irrigation by planting with a small-plot seeder and at Laird in a commercial field. Two experiments were conducted. In the first, single applications of two fungicides, Rovral and Sportak, were compared with a check. These fungicides had shown some promise in 1985 tests. Two dates of application, corresponding to the late rosette-early bud stage and the mid-late bud stage, were tested. On each date two doses were tested, a "regular" dose, and half the regular dose. In the second experiment, the effects of single and multiple applications on up to 3 spray dates were tested using Rovral or Sportak. A total of eight treatments with each fungicide resulted. A 6-replicate split-plot design was used, with fungicide as the main plot factor and spray date combinations as the subplot factor. The spray dates varied from mid-bud to full bloom, according to the location. In all tests the canola cultivar was Westar.

In both experiments at both locations disease was assessed in August when the plants were mature. Two hundred plants were removed from each plot and categorized according to severity of lesions on the stems. Disease incidence (DI) in each plot was determined simply as the percentage of plants with disease symptoms. Mean disease severity in each plot was also expressed on a percentage basis by calculating a disease index from the number of plants in each severity category. The descriptions of the five categories and the method of calculation of the disease index is shown in Table 1.

Table 1. Disease rating system used in assessment of disease index.

| Numerical value<br>of Severity Category | Description                                                             |
|-----------------------------------------|-------------------------------------------------------------------------|
| 0                                       | no lesion on stem                                                       |
| 1                                       | lesion on one side of stem                                              |
| 2                                       | more than 1/2 of stem girdled by lesions                                |
| 3                                       | more than 1/2 of stem girdled, plant prematurely ripened, seeds healthy |
| 4                                       | plant prematurely ripened, pods shrunken                                |

$$\text{Disease index} = \frac{(\text{No. of plants in a category} \times \text{Numerical value for category})}{\text{Total no. of plants} \times \text{Maximum category value (4)}} \times 100$$

In 1987 two experiments were planted at both Saskatoon and Melfort. However, the plots at Melfort were subsequently ploughed down due to weed infestation and drought damage. In both experiments more than one cultivar was used; in addition to Westar, which is highly susceptible to blackleg, cultivars with more resistance were included. This was because studies in 1986 had suggested that useful levels of control from a fungicide might be masked under heavy disease pressure, such as occurs in Westar when it is grown



on a short rotation. In the first experiment Sportak was tested on Westar and DN 188 (a breeding line with intermediate resistance to blackleg, subsequently registered in Canada as the cultivar Profit). All possible combinations of single, dual and triple applications on three spray dates were tested, as in a similar experiment in 1986. However, in contrast to the 1986 tests, a wetting agent (surfactant) was mixed with the fungicide before spraying and the dates of application were earlier. In the second experiment single applications on three dates of the new fungicide flutriafol (IMPACT) were evaluated using Westar, DN 188 and Global (a cultivar resistant to blackleg).

In both tests a six-replicate split-plot design was used, with cultivar as the main plot factor and spray treatments as the subplot factor. Disease was assessed at plant maturity by the same method as used in 1986. However, ratings were done on different dates for different cultivars because of differential maturity.

In 1988 two experiments of limited scope were done. In one test single applications at a very early growth stage (early rosette) were made with each of four sterol-inhibiting fungicides or with Rovral. This test involved four replications in a randomized complete block design and was repeated at North Battleford on Westar and at Maymont on Tobin. In August disease assessments were made, as described for 1986. In the other test, single, dual or multiple (up to 6) applications, starting at the early rosette stage, were tested using either Sportak or Tilt. The experiment involved four replicates and a split-plot design, with fungicide as the main plot factor and number of applications as the subplot factor. It was repeated at N. Battleford on Westar, at Maymont on Tobin and at Saskatoon on DN 188. Disease was assessed in August, as for the first test.

#### Use of flutriafol as a seed treatment and fertilizer coating

In early 1987 reports from Australia suggested that excellent control of blackleg could be achieved by coating phosphatic fertilizers with the fungicide flutriafol. Consequently, in 1987 preliminary experiments were done in which either treated seed or fertilizers with coated flutriafol were used. The fertilizers were coated by simply spraying the fungicide on the granules. The fungicide was applied to each of 11/51/0 and 34/0/0 at two doses. Also, seed was treated with the fungicide at two doses. Thus, there were eight treatments in the experiment: coated 11/51/0 plus non-treated seed; non-coated 11/51/0 plus treated seed; coated 34/0/0 plus non-treated seed; non-coated 34/0/0 plus treated seed, all at two doses. In the treatments with 11/51/0, the fertilizer was drilled with the seed but in those with 34/0/0 it was broadcast and incorporated before seeding. The treatments were replicated 6 times and the experiment was repeated at Saskatoon and Melfort, in both cases with cultivar Westar. Disease was assessed in August by the method described above.

In 1988 a similar experiment was carried out at Saskatoon, but with only 4 replicates and using DN 188 instead of Westar. The fertilizers were coated with flutriafol by the manufacturer. Three additional treatments were included, an untreated check and checks with 11/51/0 and 34/0/0 respectively. The test in 1988 was also set up with large enough plots that it was possible to collect plants at intervals during the growing season, yet leave enough for disease assessment in August. Plants were collected from all plots on eight



dates during the growing season, starting at the cotyledon stage and continuing until early bloom. When the plants were large enough, they were separated into components such as cotyledons and true leaves. The plant material was stored in the deep freeze until January 1989. Subsequently analyses of the plant material to detect residues of flutriafol have been conducted by solvent extraction and gas chromatography. This allows comparison of uptake and persistence of the fungicide in the plant in relation to different methods of application. Ultimately it will be necessary to determine if fungitoxic levels of flutriafol are present in the plant and if so, at what stages of growth.

#### Epidemiological studies

Experiments were conducted in 1988 in which the process of infection and the pathway of spread of the blackleg fungus in canola plants were followed. This was stimulated by recent work on winter cultivars in Britain that showed how systemic growth of the fungus from leaf lesions through the petiole is the major mechanism leading to severe basal stem cankers. Thus, an objective of our studies is to obtain a better understanding of the epidemiology of blackleg in spring canola in western Canada, in particular in relation to cultivars of different resistance. This could provide information to plant breeders relevant to the development of new resistant cultivars, but it is also of fundamental biological interest. In addition, by showing when critical events in infection and symptom development take place, it may be possible to explain why fungicides may or may not work and what needs to be done to improve their efficacy.

After preliminary experiments in the greenhouse, a field test was set up at Saskatoon under irrigation. Four cultivars representing a range of resistance were used: Westar, DN 188, Global, and Cresor (a highly resistant European type). The test was seeded on land with infested residues from 1986 to ensure abundant natural inoculum. Petioles and stems from plants with and without leaf lesions were sampled on 8 dates throughout the summer. After surface disinfection the plant parts were cut up and pieces were plated on an agar medium in sequential order. After incubation, *Leptosphaeria maculans* was identified in the isolation plates so that it was possible to detect the presence of latent (symptomless) infections in the plant parts and determine the extent of systemic growth from an initial point of penetration.

#### Cultivar reaction

In 1986, 1987 and 1988 blackleg nurseries were planted at Melfort on land where infested residues from a previous canola crop were present. The goal was to subject the entries in the nurseries to high disease pressure, although due to dry weather, this was not always achieved. The entries in the nurseries each year consisted mainly of the advanced breeding lines in the western Canada Co-op A tests (*B. napus* and *B. campestris*). However, additional entries were sometimes included, particularly old cultivars such as Midas. The experimental design was a 4-replicate randomized complete block in each year, but plot size was either 3- or 6-rows, depending on availability of land. In August plant samples were taken from the plots and assessed for disease by the method described above.

RESULTS AND DISCUSSION  
FORECASTING SCLEROTINIA BASED ON PETAL INFESTATION  
Large scale studies

Copies of brochures and other printed materials which explain the basis of the project and invite grower participation are attached to this report as Appendix A. The brochures were mailed to growers in the Melfort area in 1986, 1987 and 1988 and were distributed, as needed, in the Meadow Lake, Makwa, Shellbrook, Carrot River and Outlook areas. Because of unfavorable weather causing poor crop growth and low canola prices, grower response was poorer in all three years than in 1985.

The results of studies in 1986 are described in detail in the M.Sc. thesis of T.K. Turkington (13). An abstract of the thesis is attached to this report as Appendix B. In brief, the results can be presented in terms of forecasting accuracy, where the forecast disease risk based on PPI at early bloom is compared with the actual DI (Table 2).

Table 2. Summary of forecast disease risk based on percentage petal infestation at early bloom and actual disease incidence in four sampling areas, 1986.

| Region               | Forecast disease risk | <u>Actual disease incidence</u> |          |      |
|----------------------|-----------------------|---------------------------------|----------|------|
|                      |                       | Low                             | Moderate | High |
| Melfort-Carrot River | Low                   | 72                              | 4        | 1    |
|                      | Moderate              | 1                               | 0        | 0    |
|                      | High                  | 0                               | 0        | 0    |
| Shellbrook           | Low                   | 12                              | 1        | 1    |
|                      | Moderate              | 0                               | 0        | 0    |
|                      | High                  | 0                               | 0        | 0    |
| Meadow Lake          | Low                   | 17                              | 5        | 0    |
|                      | Moderate              | 3                               | 2        | 0    |
|                      | High                  | 0                               | 0        | 0    |
| Makwa                | Low                   | 1                               | 6        | 3    |
|                      | Moderate              | 0                               | 0        | 0    |
|                      | High                  | 0                               | 0        | 0    |

It is evident that forecasts in 1986 were relatively accurate, with the exception of crops in the Makwa area. The systematic underestimation of DI at Makwa was believed to be due either to collection of petal samples at an inappropriate time, or changes in PPI after petals were sampled. Many of the petal samples were collected during moderate to heavy rainfall and it was thought that this might cause spores to wash off petals and disease risk to be underestimated. Alternatively PPI may, indeed, have been low at early bloom, but due to rainfall at that time more sclerotia germinated and PPI increased by full and late bloom. With prolonged flowering in the crop DI at the end of the season may have been more of a reflection of PPI at full or late bloom than at early bloom. The results at Makwa caused us to do experiments in subsequent years on monitoring changes in PPI throughout flowering. It was hoped to be able to differentiate between the two explanations for the underestimation of disease risk. The 1986 results also suggested an important role of crop density in the relationship of DI to PPI (13) and led to further investigation of that subject in 1987 and 1988.

The accuracy of forecasts based on PPI at early bloom in 1987 and 1988 is summarized in Table 3. Evidently there was a high percentage accuracy. This was partly fortuitous in that, because of the weather, most crops were at low risk and indeed, limited disease developed. A more critical test would have resulted if more fields had been shown to be at high risk. On the other hand, the figures in Table 3 do not take into account factors such as crop density and fluctuations in PPI throughout the bloom period. We have always attempted to emphasize that petal testing, like any forecasting system, only estimates disease risk at the time that samples are collected and cannot fully account for weather between flowering and harvest or other variables that may affect DI. Current studies are directed at trying to take some account of these factors in our forecasting system. Finally, it is worth noting that in at least one field in each of 1987 and 1988, where PPI suggested only moderate disease risk and where only moderate disease developed, apothecia were extremely abundant. According to traditional forecasting methods both fields would have been classified at an extremely high risk.

#### Study on adequate sample sizes

The results of this study are described in the thesis by Turkington (13) and in a subsequent publication (14) which is attached to this report as Appendix C. It was shown that collecting petals at 5-6 sites per field and testing 40 petals per site was adequate to estimate PPI with a standard error of about 5% in most fields. This level of precision is sufficient in a forecasting system where DI also depends on crop density, climatic conditions and changes in PPI. However, the study also showed that the sample size needed to measure DI with a specified level of precision was highly variable among fields. Variation was related to crop uniformity and, when lodging occurred in crops, variation in DI was very high. In future experiments involving disease assessment adjustments of sample size should be made according to crop uniformity.

Table 3. Summary of forecast disease risk based on percentage petal infestation at early bloom and actual disease incidence in 1987 and 1988.

| Region and Year                                    | Forecast disease risk | <u>Actual disease incidence</u> |          |      |
|----------------------------------------------------|-----------------------|---------------------------------|----------|------|
|                                                    |                       | Low                             | Moderate | High |
| Melfort 1987                                       | Low                   | 58                              | 1        | 0    |
|                                                    | Moderate              | 0                               | 1        | 0    |
|                                                    | High                  | 0                               | 0        | 0    |
| Meadow Lake 1988                                   | Low                   | 31                              | 5        | 1*   |
|                                                    | Moderate              | 4                               | 0        | 0    |
|                                                    | High                  | 0                               | 0        | 0    |
| *Crop extremely dense, flooded and severely lodged |                       |                                 |          |      |
| Outlook 1988                                       | Low                   | 25                              | 0        | 0    |
|                                                    | Moderate              | 0                               | 0        | 0    |
|                                                    | High                  | 0                               | 0        | 0    |

#### Modification of Isolation Medium

The results of this study are described in the thesis by Turkington (13). The medium which was eventually chosen for plating petals and used from 1986 onwards was Difco potato dextrose agar containing 25 ppm streptomycin sulfate and 25 ppm anhydrous ampicillin. This medium allowed the identification of *S. sclerotiorum* after 3 1/2 to 4 days in contrast with 5 days on the medium used previously. Identification is based on rapid growth, white mycelium, limited development of aerial hyphae and characteristic branching of the hyphae at the margin of the colony.

#### Feasibility of do-it-yourself petal testing

The results of this study, conducted in 1987, are reported in the M.P.M. thesis of D. Kaminski (1). A summary of this thesis, which was distributed to the growers who participated, is attached to this report as Appendix D. The results were very encouraging in that growers obtained PPI values and levels of contamination on their isolation plates that were not significantly different from those of trained technicians working in a lab. The growers who participated in this study ranged in age from 19 to over 70 and had maximum educational backgrounds ranging from Grade 8 to a bachelor's degree. Thus, a do-it-yourself kit is clearly feasible.



Part of the material prepared by Kaminski (1) to instruct growers how to set up the petal test consisted of a video. In 1988 this video was revised slightly to give it a more general context. It was hoped that growers in the Melfort and, perhaps, other areas would use it with a kit that we provided (see Appendix F attached) to set up petal tests. Although we undertook to read the results of petal tests, we expected to make more time available for other work by encouraging growers to do their own tests. However, the drought in much of Saskatchewan removed most of the need for petal testing. One grower at Meadow Lake used a kit and three growers used kits as part of Grow With Canola on-farm demonstration projects organized by Messrs. Eugene Bendig and Jim Bessel. With the drought, the results of these petal tests all showed low disease risks; some problems were also encountered in shipping petri plates by bus after the tests had been set up. Thus, the use of test kits by growers was not an unmitigated success in 1988 and further evaluation in 1989 is necessary.

The further development and eventual commercialization of do-it-yourself petal testing kits will partly depend on the outcome of patent applications\* filed in the U.S. and Canada on our behalf by Canadian Patents and Developments Limited, Ottawa. We have heard unofficially, but so far without written confirmation, that the U.S. application has been allowed. One gap at the moment in the process of do-it-yourself petal testing is the inability of growers to read the test results themselves. Reading the results requires more technical knowledge than setting the test up because it necessitates discriminating between Sclerotinia sclerotiorum and other fungi which grow from petals in the isolation plates.

In our opinion it would be desirable to teach growers how to read the results of their own petal tests rather than have them take the test plates to a technical expert. In the first place this would eliminate the need to transport the plates from the farm. Perhaps more important, it might eliminate the involvement of a third party in decisions about spraying crops based on the test results. Such decisions could occasionally result in litigation; test kits used exclusively by growers could be sold with appropriate legal disclaimers attached.

It may be possible to teach growers how to read petal test results themselves by developing a manual of color photographs. These photographs would enable growers to differentiate between Sclerotinia and other fungi and thereby calculate PPI of their samples. It had been intended to begin work on a manual of color photographs in 1988. However, the drought in N.E. Saskatchewan and need to move our lab to Meadow Lake and set up a new network of co-operators simply did not leave time for this task. It will be given a high priority in 1989. A photographic manual for identification of Sclerotinia will be useful even if petal test results are eventually read by "technical experts" rather than farmers.

\*Morrall, R.A.A., Turkington, T.K., Gugel, R.K. and Rude, S.V. Forecasting the risk of sclerotinia stem rot in crops. U.S. Patent Application 07/050,330. Filed May 18, 1987 (Pending).  
Morrall et al. Idem. Canadian Patent Application Serial No. 557,386. Filed January 26, 1988 (Pending).

Fine-tuning the forecasting system

The results of studies of long-term changes (i.e. during the flowering period) in PPI at Melfort and Meadow Lake in 1987 and 1988, respectively, form part of the Ph.D. thesis of T.K. Turkington. A summary of some of the more important results in each year is presented in Figures 1 and 2 and Table 4. In both 1987 at Melfort and 1988 at Meadow Lake and Outlook, fields showed a gradual increase in petal infestation from early to late bloom; at Melfort and Meadow Lake this reflected gradually improving moisture conditions during June after dry, or relatively dry, weather in June. At Outlook in 1988, because of irrigation, increases in petal infestation during the bloom period cannot be so readily explained. However, infestation levels were generally lower than at Meadow Lake, perhaps reflecting a limited history of sclerotinia and cultivation of susceptible crops in the area.

Table 4. Summary of fluctuations in percentage petal infestation during flowering and of disease incidence in 29 canola fields at Meadow Lake in 1988.

| Field # | Mean % petal infestation |            |            | Mean disease incidence<br>(% diseased plants) |
|---------|--------------------------|------------|------------|-----------------------------------------------|
|         | Early bloom              | Full bloom | Late bloom |                                               |
| 1       | 2                        | 30         | 38         | 1                                             |
| 2       | 13                       | 23         | 27         | 4                                             |
| 3       | 4                        | 24         | 27         | <1                                            |
| 4       | -                        | 45         | 57         | 1                                             |
| 5       | 9                        | 27         | 28         | 2                                             |
| 6       | 5                        | 50         | 58         | 1                                             |
| 7       | 30                       | 58         | 77         | 12                                            |
| 8       | 18                       | 54         | 59         | <1                                            |
| 9       | 1                        | 37         | 46         | 6                                             |
| 10      | 2                        | 37         | 45         | 2                                             |
| 11      | 10                       | 47         | 59         | 3                                             |
| 12      | 6                        | 45         | 57         | 4                                             |
| 13      | 0                        | 40         | 68         | <1                                            |
| 14      | 7                        | 44         | 59         | 6                                             |
| 15      | -                        | 53         | 77         | 2                                             |
| 16      | 14                       | 72         | 88         | 1                                             |
| 17      | 2                        | 50         | 66         | 2                                             |
| 18      | 5                        | 61         | 68         | 1                                             |
| 19      | 4                        | 38         | 52         | 3                                             |
| 20      | -                        | 29         | 36         | 4                                             |
| 21      | 4                        | 15         | 18         | 1                                             |
| 22      | 39                       | 62         | 51         | 7                                             |
| 23      | 15                       | 74         | 69         | 8                                             |
| 24      | 43                       | 47         | 56         | 15                                            |
| 25      | 35                       | 74         | 70         | 22                                            |
| 26      | 22                       | 51         | 54         | 13                                            |
| 27      | 34                       | 67         | 77         | 21                                            |
| 28      | 10                       | 44         | 35         | 60*                                           |
| 29      | 34                       | 41         | —          | 8                                             |

\*Crop flooded and severely lodged.

Figure 1. Changes in petal infestation during the bloom period in three canola fields near Melfort in 1987.

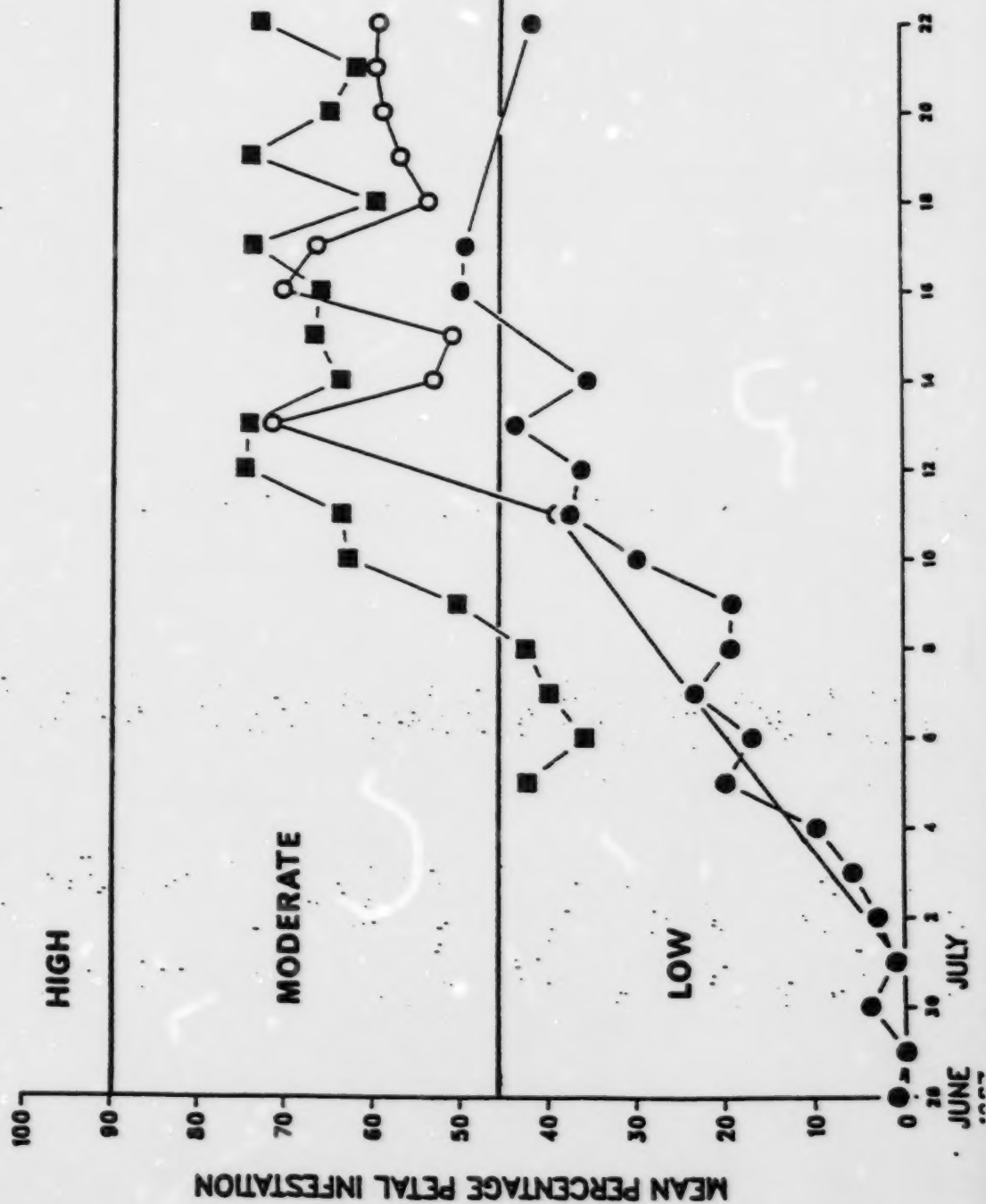
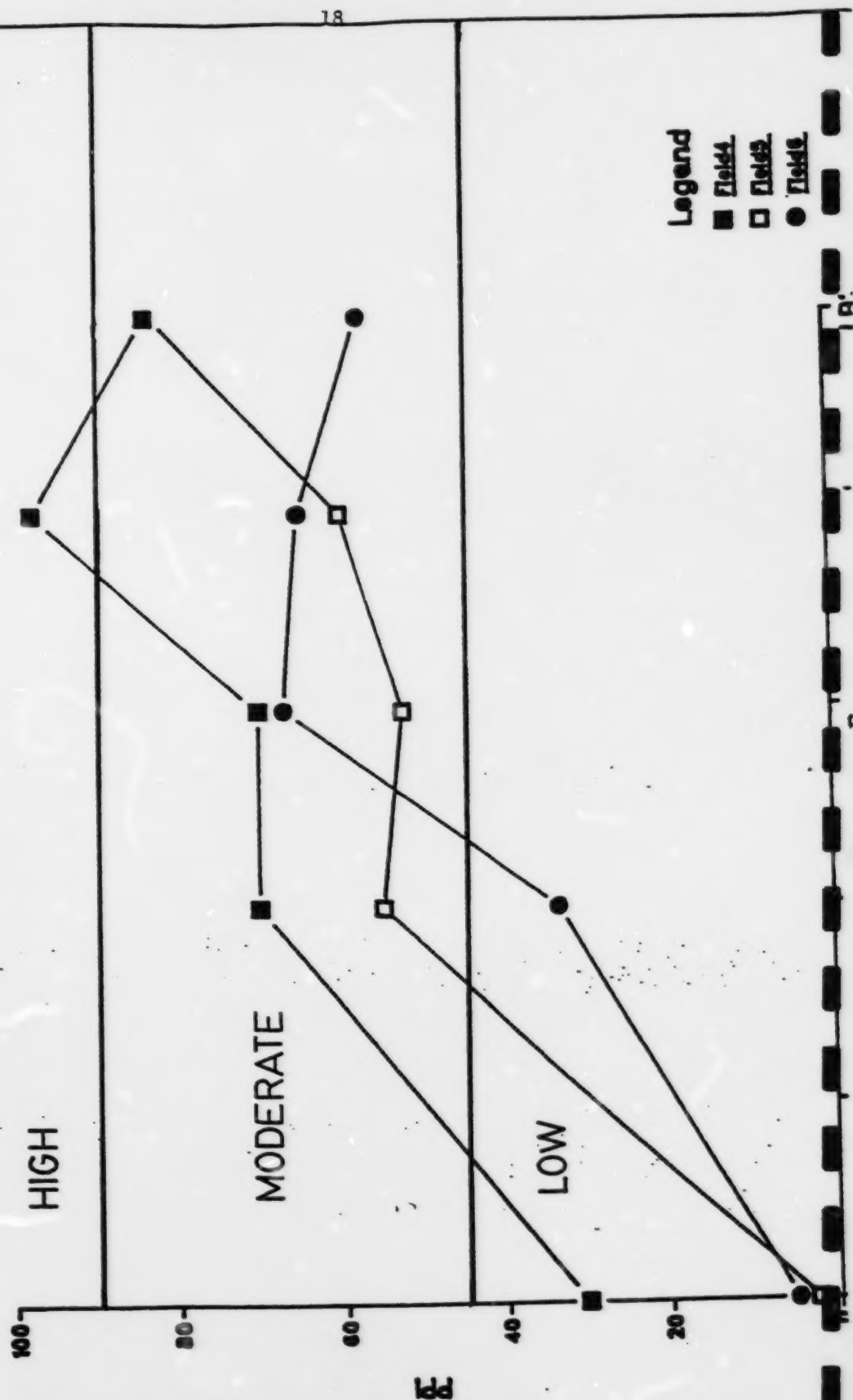


Figure 1. Changes in petal infestation in late June and July in three canola fields near Meadow Lake in 1988.  
 Key: EB-early bloom, FB-full bloom, LB-late bloom, LB1-beginning of late bloom, LB2-end of flower.

# Changes in percentage petal infestation (PPI) during the bloom period for three fields





The ultimate objective in these studies is to use multiple regression analysis to study the relative importance of inoculum on petals at different stages of flowering in determining DI in crops. These analyses have not yet been carried out. A potential practical outcome is that the results may permit optimum timing of fungicide applications to control sclerotinia, since other studies have shown that fungicides can give good control even when applied at late bloom, given the right conditions. In other words, fungicide application can and should be delayed until inoculum levels justify it. It is noteworthy that, based on petal infestation levels at early bloom alone, only one of the study fields in 1987 (Figure 1) would have been expected to have DI values above about 2%. Most of the disease which did develop in 1987 resulted from inoculum at a later flowering stage. On the other hand, casual inspection of the data for 1988 in Table 4 suggest that PPI at early bloom is the most important determinant of DI.

The results of studies of diurnal and weather-related changes in PPI done in 1987 and 1988 will also form part of the Ph.D. thesis of T.K. Turkington and are not presented in detail here. In brief there were consistent diurnal changes in percentage petal infestation in both years, but these and changes due to weather conditions such as rainfall were less than expected. Generally PPI increased from early morning to noon, provided rain was not falling, and then it levelled off in the afternoon. However, there was seldom more than a 30% change. Consequently, while petal sampling is best carried out on dry afternoons to avoid underestimating disease risk, sampling at other times would not be a major limitation to its usefulness. Other factors are likely to have a greater impact on the accuracy of the forecast.

A third aspect of the study on fine-tuning that was initiated in 1988 was to attempt to study more critically the influence of crop canopy on the relationship between petal infestation and disease incidence. The plots that were planted in Saskatoon and Melfort were eventually abandoned because the drought and heat prevented the production of inoculum and development of disease. The data obtained after flowering from the 29 fields where PPI was monitored at Meadow Lake have not been summarized yet; the intention is to use them as additional variables in multiple regression analyses. It will be necessary to repeat both types of experiment in 1989 to confirm the quantitative relationship of DI with crop density.

#### CHEMICAL CONTROL OF SCLEROTINIA Half-dose and split applications

The results of tests conducted in 1986 at Meadow Lake are included in an unpublished manuscript submitted to the Canadian Journal of Plant Pathology (7). This will eventually be resubmitted after revision and inclusion of results from the 1987 tests from Gronlid. A copy of the unpublished manuscript is attached to this report as Appendix F. In both years the tests confirmed the fact that at relatively low disease pressure half doses of Benlate, Rovral and Ronilan were almost as effective as full dose applications. Dual half-dose applications at early and full bloom, including with combinations of two fungicides, were very effective. The results suggested options in chemical control not previously available to growers.

### Late bloom fungicide application

The results of tests done in 1987 and 1988 are the subject of the M.Sc. thesis project of S.V. Rude (11). Mr. Rude is in the final stages of writing his thesis and is expected to defend it in April 1989. An abstract of the thesis and a technical report based on part of the 1987 studies (12) are attached to this report as Appendix G. Although in a number of the tests, especially those done in 1988, disease levels were much lower in the check plots than expected and did not warrant collecting results, the "successful" tests all pointed in the same direction. Significant control was achieved with late bloom fungicide application in all cases and a high level of control was obtained when inoculum had not become abundant in the plots until full of late bloom. In tests where plots were sprayed with half the recommended dose of Benlate, DI was slightly higher, but not significantly different from DI in plots sprayed with the full dose. Nozzle type generally had little effect on efficacy of control, at least not at the disease levels experienced in the tests.

The results of these experiments might have been more definitive if higher disease levels had been achieved in some of the tests. Nevertheless they suggest a place for late-bloom fungicide application in the management of sclerotinia stem rot. When inoculum is not abundant until late bloom, DI will probably be relatively low under most environmental conditions. This probably would not be sufficient to justify applying a fungicide at the full dose, even if 100% control were achieved. However, application at a reduced dose, which gave almost as much control, might be economically justified because the cost would be much less.

### Application technology

The experiments conducted in 1987 and 1988 in conjunction with Rogers Engineering were reported in the Pesticide Research Report (4, 5, 6). Copies of the reports are attached as Appendix H. There appeared to be a clear difference between Benlate and Rovral in efficacy of control at less than the recommended dose; Rovral gave significant reductions in DI compared with the check only in treatments at 0.5 kg a.i./ha in 1987. In the test with Benlate in 1987 there were few significant differences among treatments other than the major difference between the check and all other treatments. However, the ranking of treatments suggested that the nozzle type producing smaller droplet sizes gave the best control. Furthermore, in one case a high level of control was achieved with only 1/4 the recommended fungicide dose. In the 1988 test with Benlate disease pressure was low and only tentative conclusions could be drawn. Generally DI was inversely proportional to fungicide dose, but half the recommended dose gave a high level of control in two cases. Of particular interest was the fact that treatments with volumes of carrier fluid considerably lower than those normally used by growers (i.e. 100 L/ha) were equally effective as the normal volumes.

There is clearly need for further work in this area because the ability to achieve effective control of sclerotinia with reduced fungicide doses and low volumes of carrier fluid is of great economic interest. Some of the treatments tested in 1988 need to be retested under higher disease pressure. Studies done by Rogers Engineering Ltd. under a separate ADF contract on spray deposition on canola (10) suggest reasons for the results we obtained. It

appears that combinations of spray nozzles and pressure that produce fine spray droplets result in greater total deposition of fungicide on the plants.

### Testing New Products

The results of tests in 1986, 1987 and 1988 have been reported in the Pesticide Research Report (2, 15, 16) and copies are attached as Appendix I. Several fungicides such as Easout and Sportak gave good control of sclerotinia stem rot and may eventually be registered in Canada. In addition, a new safer-to-use dry flowable formulation of Benlate tested in 1987 gave good control.

### INTEGRATED CONTROL OF BLACKLEG Foliar fungicide applications

The results of experiments conducted at Saskatoon and Laird in 1986 are reported in detail in the M.Sc. thesis of K. Xi (17). An abstract of the thesis is attached as Appendix J. In Experiment 1, in which single applications of Rovral or Sportak were tested on two dates at two locations, few significant differences in DI or disease index among treatments were achieved. No significant differences in yield occurred. Generally Sportak gave better control than Rovral (Table 5). However, even at Saskatoon, where lower disease levels occurred (Table 5), the maximum reduction in disease index compared with the check was 30%. The corresponding figure at Laird was only 5.5%. It is unlikely that a spray treatment giving this effect would usually be economical.

Table 5. Means of final disease incidence and index and of yield in Experiment 1 at Saskatoon and Laird in 1986.

| Treatment | Disease incidence | Saskatoon     | Yield (g/plot) | Disease incidence | Laird         | Yield (g/plot) |
|-----------|-------------------|---------------|----------------|-------------------|---------------|----------------|
|           |                   | Disease index |                |                   | Disease index |                |
| 1         | 72.6              | 40.6          | 364            | 94.9              | 69.9          | 115            |
| 2         | 48.7              | 28.3          | 356            | 90.6              | 66.1          | 106            |
| 3         | 56.7              | 31.6          | 410            | 93.5              | 69.4          | 109            |
| 4         | 54.7              | 30.5          | 382            | 91.9              | 71.5          | 110            |
| 5         | 67.0              | 39.8          | 356            | 93.0              | 65.2          | 121            |
| 6         | 58.8              | 34.2          | 372            | 95.0              | 70.2          | 107            |
| 7         | 60.5              | 34.8          | 397            | 93.7              | 70.4          | 121            |
| 8         | 62.9              | 37.5          | 403            | 96.0              | 73.0          | 102            |
| 9         | 66.7              | 40.8          | 412            | 95.8              | 69.7          | 104            |
| SE        | 4.87              | 4.73          | 35.65          | 2.05              | 1.25          | 10.28          |

SE = standard error

\*1 = Check; 2 = Sportak, regular rate and early spray; 3 = Sportak, half rate and early spray; 4 = Sportak, regular rate and late spray; 5 = Sportak, half rate and late spray; 6 = Rovral, regular rate and early spray; 7 = Rovral, half rate and early spray; 8 = Rovral, regular rate and late spray; 9 = Rovral, half rate and late spray



In Experiment 2 in which single, double, and triple applications of Sportak and Rovral were tested differences between fungicides were slight and non-significant except with respect to DI at Laird. Accordingly, the data both fungicides were combined for comparison of spray treatments (Table 6).

Table 6. Means of final disease incidence and index and of yield in Experiment 2 at Saskatoon and Laird in 1986.

| Factor      | Treatment  | Saskatoon         |               |                | Laird             |               |               |
|-------------|------------|-------------------|---------------|----------------|-------------------|---------------|---------------|
|             |            | Disease incidence | Disease index | Yield (g/plot) | Disease incidence | Disease index | Yield (g/plc) |
| Fungi-cide  | Sportak    | 62.6              | 37.0          | 282            | 86.1              | 55.7          | 128           |
|             | Rovral     | 68.6              | 41.7          | 257            | 90.7              | 59.0          | 129           |
| SE          |            | 2.12              | 2.63          | 13.25          | 0.83              | 1.70          | 7             |
| Spray dates | Check      | 71.5              | 41.3          | 274            | 96.0              | 64.9          | 129           |
|             | Date 1     | 68.0              | 41.3          | 281            | 88.4              | 55.1          | 135           |
|             | Date 2     | 67.5              | 41.1          | 275            | 88.2              | 54.1          | 142           |
|             | Date 3     | 73.2              | 42.0          | 257            | 92.7              | 60.4          | 112           |
|             | Date 1/2   | 59.8              | 36.0          | 297            | 86.1              | 59.4          | 129           |
|             | Date 1/3   | 65.0              | 39.1          | 240            | 86.0              | 54.7          | 121           |
|             | Date 2/3   | 65.3              | 41.9          | 265            | 88.5              | 58.5          | 123           |
|             | Date 1/2/3 | 52.7              | 31.7          | 266            | 81.3              | 52.0          | 137           |
| SE          |            | 2.04              | 3.16          | 19.63          | 1.73              | 2.84          | 8.54          |

SE = standard error.

At both locations the differences in disease level between the check and the combined spray plots were generally significant. However, there were few significant differences among specific treatments, even though there was a general trend of decreasing disease with increasing numbers of sprays (Table 6). No significant differences in yield occurred. As in Experiment 1, levels of disease control were low and would certainly not be economically worthwhile relative to the cost of fungicides. Maximum reductions in disease index were 23% at Saskatoon and 20% at Laird. It was believed that the poor control at both locations might have been because initial fungicide applications were not made early enough in crop development. However, subsequent years' work did not bear this out.

Experiments conducted at Saskatoon in 1987 with Sportak and Impact were reported in the Pesticide Research Report (8, 9). Copies of these reports are attached as Appendix K. The main differences shown in these



tests were among the cultivars Westar, DN 188 and Global. Effects of spraying, though sometimes significant and related to number of applications, were very limited. For example, the maximum reduction of disease index (% disease severity in Appendix K) compared with the relevant check was 21% in the test with Impact and 23% in the test with Sportak. Thus, in the tests in 1987, even though a surfactant was used with Sportak, even though spraying began at an earlier growth stage than in 1986 and even though cultivars with greater resistance than Westar were used, economic control was not achieved.

The experiments conducted in 1988 at Saskatoon, North Battleford and Maymont were reported in the Pesticide Research Report (18, 19). Copies of these reports are attached as Appendix L. The emphasis in these limited-scale field tests was (a) to test fungicide applications at, or initiated at, a very early stage of crop growth, (b) to try fungicides with known systemic activity in plants and (c) to see if control was possible with repeated spraying throughout the growing season. The results suggested that none of these things were effective. Limited control was achieved with any of the treatments, including those involving 5 or 6 fungicide applications!

The results of four years' work with foliar fungicide application to control blackleg are not encouraging and do not suggest that this approach should be pursued further for the time being. When more is known about the epidemiology of the disease in western Canada and the systemic spread of the pathogenic fungus in the plant, it may be worthwhile resuming work and attempting to integrate foliar fungicides with other methods of control.

#### Use of flutriafol as a seed treatment and fertilizer coating

In the experiments conducted in 1987, no significant differences among treatments in emergence, disease levels or yield were achieved. Disease severity was extremely high in the test at Saskatoon. It was possible that the lack of effect was related to the method of treating the fertilizer with flutriafol and the extreme susceptibility of Westar to blackleg. In the Saskatoon test control effects might have been masked by very high disease levels.

Part of the results of the 1988 test with DN 188 at Saskatoon were reported in the Pesticide Research Report (20). A copy is attached as Appendix M. High levels of control were not achieved in this test, but they were enough to warrant further work. Both fertilizer coating and seed treatment reduced disease relative to the pertinent checks but fungicide dose had no significant effects. Flutriafol in combination with 11/51/0 was significantly better than in combination with 34/0/0 in reducing DI but not disease severity. Seed treatment without fertilizer coating resulted in significantly lower DI values than fertilizer coating without seed treatment. Reductions in disease severity relative to the pertinent checks were mostly between 20 and 35% and might, therefore, economically justify the cost of treating seed or fertilizer with the fungicide. Moreover, it is possible that the control achieved in this experiment by fertilizer coating or seed treatment separately would be additive.

Subsequent analyses of the plant material collected in this test have provided some explanation of the results. Flutriafol residues were detected in plant material from all treatments except the checks during the seedling and rosette stages. It remains to be determined if the residues are present at fungitoxic levels. However, the fungicide appears to be more readily detectable in plants from treatments in which fertilizer was coated rather than seed treated. Moreover more residues are detectable in treatments with coated 11/51/0 than with coated 34/0/0. It may be that the plant can take the fungicide up from the seed coat for only a very brief period during and after germination, but for a longer period from coated 11/51/0 banded with the seed. This would lend credence to the idea that control from seed treatment and fertilizer coating might be additive. The two treatments together might provide adequate protection from infection for a critical period in the early growth of the plant. These ideas will be investigated in more extensive experiments in 1989.

#### Epidemiological Studies

This work was initiated in 1988 and forms part of the Ph.D. thesis project of K. Xi. In the experiment at Saskatoon with four cultivars differing in resistance to blackleg, the fungus was readily isolated from components of plants with, and without, symptoms. There were three major findings, all of which require confirmation or further, more detailed investigation.

(a) There was a major difference between Westar and the other cultivars in speed of mycelial development in the petiole, especially early in the season. Thus, part of the high susceptibility of Westar may be due to the ability of the fungus in this cultivar to spread rapidly from infected cotyledons and true leaves into the stem base, where a basal canker may develop.

(b) There was a high level of latent or symptomless infection of the stems at the budding and flowering stages in all cultivars. This finding was confirmed in a test of plants collected in a field of cv. Tobin. Thus, disease development in a crop may be less a function of availability of inoculum and conditions conducive to infection as of environmental factors that trigger conversion of a latent infection into an infection with symptoms. This phenomenon of latent infection needs further investigation under a variety of environmental conditions and through the entire development of the plant. If latent infection is also common at very early stages of growth it might explain the lack of disease control with foliar fungicide application and indicate how chemical control may be enhanced.

(c) The percentage of latent stem infection actually decreased in the second half of the growing season, especially in the more resistant cultivars. If this finding can be confirmed, it will suggest another component of resistance that may be useful to plant breeders. It may be that the plant can produce fungitoxic compounds such as phytoalexins that can protect it from symptom development.

The results of disease assessments in the blackleg nurseries planted at Melfort from 1986 to 1988 were summarized and presented at the Western Expert Committee on Grain Diseases meetings in February each year. Copies of these summaries are attached as Appendix N. These data, along with those presented by other pathologists, have contributed to the recommendations by pathologists concerning registration of new cultivars. It is noteworthy that, in contrast with 1985, it is now widely accepted that Westar is one of the most susceptible cultivars to blackleg. Furthermore, a significant, if not the dominant, consideration in proposals for registration in February 1989 was evidence of reduced blackleg susceptibility. For example, the registration of DN 188 (Profit) was supported by data not only from disease nurseries, but also from two of our fungicide trials in 1987 (Appendix K).

#### CONCLUSIONS AND IMPACT

SCLEROTINIA. Much of what we set out to achieve in 1986 has been done, despite some problems related to successive years of spring drought at Melfort and the fact that blackleg is a more serious problem than sclerotinia in that area. We have continued to develop and refine the use of petal testing as a means for forecasting disease risk. Our mistakes as well as our successes have led us to try to build into the system means of accounting for crop density and for fluctuations in petal infestation throughout the bloom period. The latter is worthwhile only because of what we have learned about timing fungicide applications.

We have shown that sampling 40 petals at each of five sites in a field is adequate for practical purposes of forecasting, i.e. it will give a result that is 95% correct 19 out of 20 times. We have also shown that diurnal patterns and changes due to weather conditions do not make a major difference in the accuracy of petal testing; however sampling in the afternoon under dry conditions is optimal to recognize disease risk. A first step was taken in developing a home-petal test kit for growers to use themselves and which will eventually be commercialized. We have shown that growers can readily set the test up themselves, but work still needs to be done on how growers would read the test results. We believe that it is only a matter of time before petal testing becomes commonplace for determining the risk of sclerotinia and making decisions about the economics of chemical control. The more that canola prices fluctuate, the more that this will be useful. Already growers and extension agents in areas other than where we have worked (including Manitoba and Alberta) have indicated an interest in trying out petal testing. Finally, even if petal testing by agar plating were eventually replaced by an immunological test for sclerotinia on petals, such as an ELISA, the data we have generated on adequate sampling, time of sampling, fluctuations in petal infestation and crop density would all be relevant to the new test.

In the area of chemical control our main success has been in elucidating the options for growers that can save money on unnecessary, or unnecessarily expensive, fungicide applications. We have repeatedly demonstrated that reduced doses of fungicides can give substantial control of sclerotinia and excellent control when disease pressure is low. We have



shown that even late bloom fungicide application can give control when inoculum is not abundant during early flowering. We have shown that split applications give by far the best control. Thus, fungicide applications can be rationalized in relation to changes in disease risk demonstrated by petal testing. A good example of where split applications based on petal testing could probably improve control can be drawn from a careful comparison of our own fungicide tests in 1987 and 1988 (2, 4, 5, 16, Appendices H and I). In both years the single fungicide applications used in these tests were made at about the same growth stage. Similar significant differences between various treatments and checks were obtained in both years. Yet control (i.e. % reduction of DI compared with the check) was consistently less in 1988 than in 1987. In 1988 the crop was probably exposed to high levels of inoculum for a longer period than in 1987. If the single fungicide application at the recommended dose had been split between two half-dose applications a week apart, more complete control would have undoubtedly resulted.

We were also successful in the stated goal of attracting the interest of an agricultural engineer to work on application technology. The work has produced interesting results that need further testing under higher disease pressure. By appropriate choice of nozzles and spray pressures it seems to be possible to reduce not only fungicide doses, but also volumes of carrier fluid. The impact of this finding on canola production may be more than immediately obvious. If chemical control of sclerotinia becomes a more economically attractive option, it might be practised even when disease risk is not high. This could have long range benefits to all growers by reducing levels of inoculum in canola production areas.

The scenario for managing sclerotinia based on petal tests and timed fungicide applications that may apply in a few years is much more complicated than that which applied when the first fungicide was registered for use in 1982. While this may be inappropriate for a few farmers, it will suit the majority who are willing to accept new technology. All aspects of agriculture depend on technology of ever-increasing complexity and the economic crisis in farming will not be resolved by avoiding it.

BLACKLEG. Work on this disease has been marked by failure and frustration. The initial promise shown by foliar fungicides, referred to in the application in 1985, has not been realized. Tests in the field have repeatedly shown that although statistically significant reductions in disease may occur, they are inadequate to increase yield enough to be of commercial interest. When this work was started it was done exclusively with Westar canola. At that time, despite much speculation, Westar had not been conclusively established as being more susceptible than other cultivars. Now the work of many people, including ourselves, has shown that Westar is extremely susceptible and significantly more than some other cultivars. However, even in less susceptible cultivars foliar fungicides do not work any better. For example, even five or six applications of Tilt or Sportak throughout the growing season in 1988 did not give adequate control in DN 188 or Tobin. There is a definite paradox when none of a series of systemic and protectant fungicides, which have considerable in vitro activity against Leptosphaeria maculans, will not control blackleg in the field. This may relate to an unusual mechanism by which the fungus invades canola plants and causes basal stem cankers. It is hoped that



further epidemiological studies of the type initiated in 1988 will help to resolve this problem.

Some glimmer of hope to control blackleg chemically comes from the 1988 experiment in which flutriafol used as a seed treatment and fertilizer coating gave up to 30% reduction in disease. It seems worthwhile, therefore, to pursue this avenue of investigation by assessing an integrated control program that might consist of both seed treatment and fertilizer coating (each potentially inexpensive) plus a single foliar fungicide application.

In early 1988 I stated that the severity of the blackleg problem in western Canada necessitated a less conservative approach towards the registration of new canola cultivars and emphasized the extremely dangerous situation that breeders, farmers and the industry had allowed to develop in recent years in canola production (3). Over the years there have been rapid changes in cultivars as dramatic improvements in yield, oil quality and early maturity were achieved by breeders. Farmers have rapidly adopted new cultivars, but they have become the victims of their own eagerness to accept technological change. In 1984 and 85 virtual monocultures of Brassica napus cv. Westar and B. campestris cv. Tobin existed in western Canada. Seed stocks of older cultivars were not maintained. However, monocultures are inherently vulnerable and blackleg on Westar provides yet another example of history repeating itself.

Farmers need, and need to be encouraged to grow, a greater variety of canola cultivars, if for no other reason than for the sake of diversity. The registration of new cultivars should not necessarily require yield, early maturity and oil content comparable to Westar. As with triazine tolerance, even partial blackleg resistance can far outweigh an inherent yield disadvantage compared with check cultivars. Fortunately, there is evidence that the situation with cultivar diversity and with blackleg reaction is improving. In February 1988 and especially in February 1989 an unprecedented number of new canola cultivars were registered. These have a somewhat diverse genetic background and most of them have a better reaction to blackleg than Westar.

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(c) Papers prepared and talks given

(i) See reference list at the end of the technical report.

(ii) Other publications from 1986-88, related to the work, but not cited in the technical report

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Appendix A. Items mailed to growers participating in Sclerotinia Project, 1986-88.

- A - Letter to growers, June 1986.
- A (i) - 1986 Brochure
- A (ii) - 1986 Sampling instructions
- A (iii) - Report on 1986 results, March 1987
- A (iv) - 1987 Brochure
- A (v) - 1987 Sampling instructions
- A (vi) - Report on 1987 results, March 1988
- A (vii) - 1988 Brochure
- A (viii) - 1988 Sampling instructions



DEPARTMENT OF  
BIOLOGY

UNIVERSITY OF SASKATCHEWAN

SASKATOON, CANADA  
S7N 0W0

Dear Canola Grower:

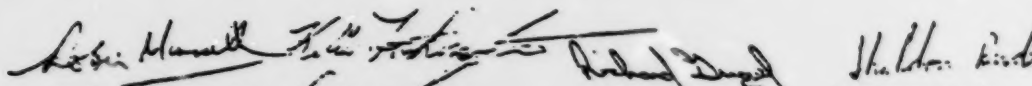
Re: Sclerotinia project

As you are probably aware from our highway signs, our mass mailings and other forms of publicity, we operated this project last year out of the Melfort Research Station. The purpose of the project is to try to develop a better method of forecasting sclerotinia stem rot on canola, and thereby rationalize the use of fungicides to control the disease. We don't have to tell you that the fungicides are quite expensive and no one would want to use them if they could be sure that they were not needed. This is more true than ever, with the price of canola down from last year, the dry weather in June and the frost of June 13.

This letter is just to let you know that we are back in operation again this year and still hoping you will bring samples to our lab. We appreciated the co-operation we received from growers last year. However, in order to improve the accuracy of our forecasting system, we feel that we need an even larger number of samples this year. We know this will be particularly difficult, since there is less acreage than in 1985. Thus, please seriously consider giving us an hour or so of your time by bringing us samples when your crop(s) are in early bloom.

Please read the enclosed brochure for more information about the project. Also, see how you could win \$300 worth of fungicide. Phone 752-3070 for further details.

Yours sincerely,

  
Robin Morrall. Kelly Turkington. Richard Gugel. Sheldon Rude.

# SCLEROTINIA PROJECT

## Year 2

Department of Biology  
University of Saskatchewan  
Saskatoon, SK S7N 0W0

OBJECTIVE: To improve the ability to forecast the severity of sclerotinia stem rot in canola crops and thereby reduce the economic risks in using fungicides for control. The project depends on growers in the Melfort area lending a helping hand by providing samples from their crops.

SPONSORSHIP: We are supported directly or indirectly by the Canola Council of Canada, the Natural Sciences and Engineering Research Council of Canada, the Agricultural Development Fund, the Agriculture Canada Research Station at Melfort and the agrichemicals industry.

WIN ENOUGH FUNGICIDE TO SPRAY 20 ACRES (RETAIL VALUE \$300)!

During the period that our lab at Melfort is open in July we shall hold four draws at about 5-day intervals. The names entered in these draws will be those of grovers who have brought samples to the lab since the previous draw. Each winner will receive enough Benlate or Rovral to treat 20 acres of canola at recommended rates. These prizes have been kindly donated by the manufacturers. Two winners will receive Benlate and two will receive Rovral. The draws will be independently supervised and the judge's decision will be final.



## HOW AND WHEN TO FIND US

When canola crops are in bloom in the Melfort area our services will be available 7 days a week. But our hours of operation will be a little different from last year. From Monday to Saturday we shall be open from 7:30 a.m. to 6:30 p.m., and on Sundays from 1:30 p.m. to 6:30 p.m. only. Our lab is easy to find. It is located in the old Horticulture building at the Melfort Research Station. Just follow the signs that say "SCLEROTINIA PROJECT".

## PHONE FOR MORE INFORMATION

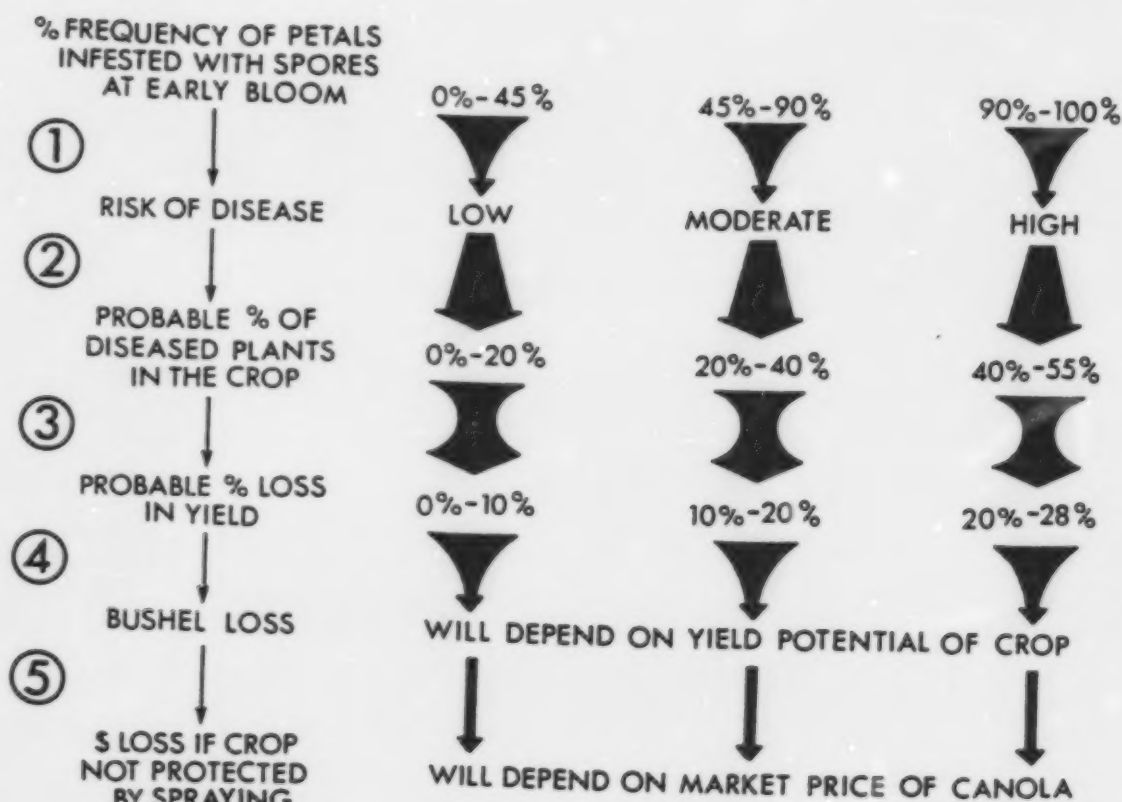
Our number is 752-3070. After hours leave a message on the answering machine and we'll call you back as soon as possible.

## CONDITIONS OF PARTICIPATION

1. If you plan to spray your crop with a fungicide to control sclerotinia, please leave a check strip down one side of the field where you collected the petal samples (see the instruction sheet). This strip is essential for us to validate our prediction system by assessing disease incidence before you swath the crop in August.
2. This project is still only a research program, not a commercial forecasting system. Thus, we must ask you to sign a legal waiver releasing us from responsibility for any decisions you make about the management of your crop based on the test results we give you.

# FORECASTING SCLEROTINIA DISEASE AND YIELD LOSSES IN CANOLA

Work done in western Canada to date suggests that, under average conditions, the relationships depicted in the chart below apply in canola crops. You may wish to use parts of this chart to help decide if spraying might pay off in your crop. However, remember that step 2 is the most variable because it depends the most on plant stand and on weather conditions during the time plants are flowering and losing their leaves. Thus, if hot dry weather occurs in late July, the actual % diseased plants and % yield loss in a crop will be less than forecast. Conversely, if unusually cool wet weather persists during late bloom, even fields forecast to be at low risk may develop moderate amounts of sclerotinia stem rot.



## AN ANSWER IN 3 - 4 DAYS?

Last year we phoned growers with the test results 5 days after they brought the petal samples in. Because of the need to spray before the crop is too advanced, we have worked hard to find a method of speeding up the test. This year we can promise you an answer in 4 days and, in most cases, we shall probably be able to phone with the results 3 days after you bring the samples in.

## GOING AWAY ON HOLIDAY AND NEED HELP TO COLLECT SAMPLES?

It is obviously impossible for us to monitor all the canola crops in and around our study area (16 townships centred on Melfort) and check when each of them reaches the correct growth stage for sampling. This would require almost daily visits in early July. For this reason we request the participation of growers in bringing the samples into our lab. However, we can undertake a limited amount of sampling if you are planning to go away on holiday and cannot collect the flowers for us. Please phone us at 752-3070 and let us know (a) when you will be away, (b) the exact land location, (c) the date the crop was seeded and (d) the variety planted. Try to give us at least three days notice of when sampling will be necessary.

## RESULTS

Next winter we shall mail everyone that participates a report explaining the results of the project.

## SCLEROTINIA PROJECT, MELFORT 1986

## HOW TO COLLECT SAMPLES

If you are willing to collect petal samples for us, this should be done about 5-6 days after the first yellow blossoms appear in the field. At this time the crop should be in stage 4.2 of flowering according to the scale on the right (See Chapter 3 of Canola Grower's Manual for more details of growth stages). The appropriate time for collecting petal samples is around what many growers would call 20% bloom (about 15 flowers open on the main stem). Collect samples in four places in the field, as described below.

Please collect samples at four sites along one side of the field which will be easily accessible in mid August. Space the four sites out as much as is practical along the field. They should be at least 50 yds apart. Walk 20-30 yds into the crop from the edge at each site to avoid sampling where the stand is weedy or otherwise atypical. If you are planning to spray the crop with a fungicide, make sure that the strip where you collected samples for us is not sprayed. We need this check strip to measure disease incidence later in the summer.

It is essential to mark the sampling sites with stakes so that we can find them in August when we come to measure disease incidence. We will provide you with 6 ft long stakes for this purpose. Please draw a rough map of the field, mark sampling sites and number them on the map from 1 to 4. When you collect the petal samples, keep those from each site in a separate bag and number each bag accordingly. Write the numbers on the tops of the stakes, too.

At each site, cut the tops off five to ten flowering shoots so that we will have at least 50 open yellow flowers from each site. Place the tops from one site in a clean (preferably new) plastic bag and number the bag appropriately. Please use a fairly large bag as it is important not to squash the petals together too much. Close the bags but do not seal them too tightly and at all times keep them as clean as possible, particularly away from soil.

When you have collected the samples from one field take the four bags to the lab at the Agriculture Canada Research Station at Melfort. Do not leave the bags in the sun and, if possible, take them to the lab no more than two hours after collection.

If in any doubt about the sampling procedure, please phone us at 752-3070. We will be happy to provide further information. Remember, the lab will be open Monday to Saturday from 7:30 a.m. to 6:30 p.m. and on Sunday from 1:30 p.m. to 6:30 p.m. during July. There will also be an answering machine for after hour messages.

## CANOLA GROWTH STAGE

0. Pre-emergence
1. Seedling
2. Rosette
3. Bud
4. Flower
  - 4.1 First flower open
  - 4.2 Many flowers opened, lower pods elongating
  - 4.3 Lower pods starting to fill
  - 4.4 Flowering complete, seed the enlarging lower pods
5. Ripening



SCLEROTINIA PROJECT

FORECASTING SCLEROTINIA STEM ROT

BASED ON PETAL INFESTATION

GENERAL RESULTS 1986

We wish to thank all those involved with the project in 1986. Despite the depressed farm economy and dry weather in east central Saskatchewan, many farmers went out of their way to provide petal samples for our lab. Although the number of samples was less than in 1985, the results still indicate the potential of the forecasting system. They also suggest the need to examine more closely some aspects of the system. We encourage you to read the rest of this report and we look for your support in the future.

SUMMARY

The study area in 1986 was to be centered around Melfort, the same as in 1985. However, dry weather in June and early July prompted us to look at other areas of the province with more rainfall. From June 28 to July 23 petal samples from approximately 145 fields were collected. Of these, 93 were from the Melfort-Carrot River area, 10 from Makva, 28 from Meadow Lake, and 14 from Shellbrook. The test results were available within three to four days. This was an improvement over 1985 when five days were needed before results could be obtained.

Fields were visited from August 18 to 26 to assess the level of disease. Assessment was not as difficult as in 1985. In most cases stakes were still standing and were relatively accessible, thanks to the cooperation of farmers. We did however miss making disease assessments in a number of fields. Most of these had been seeded with the early maturing polish-type canola. Of the 145 fields sampled in July only 128 were assessed for disease. We apologize for missing some fields and hope to prevent this in the future.

## RESULTS

### (I) LEVELS OF PETAL INFESTATION AND DISEASE INCIDENCE

In 1986 the levels of petal infestation and disease reflected environmental conditions during June and early July. Average petal infestation per field ranged from 0 to 81%. Three quarters of the fields had less than 10% petal infestation (Figure A). Average disease in August ranged from 0 to 57% diseased plants per field. Two thirds of the fields had less than 10% diseased plants (Figure B). The majority of fields with higher levels of petal infestation and diseased plants were from Meadow Lake and Makva, where environmental conditions were better for disease development.

Figure A. Observed Levels of Petal Infestation, 1986

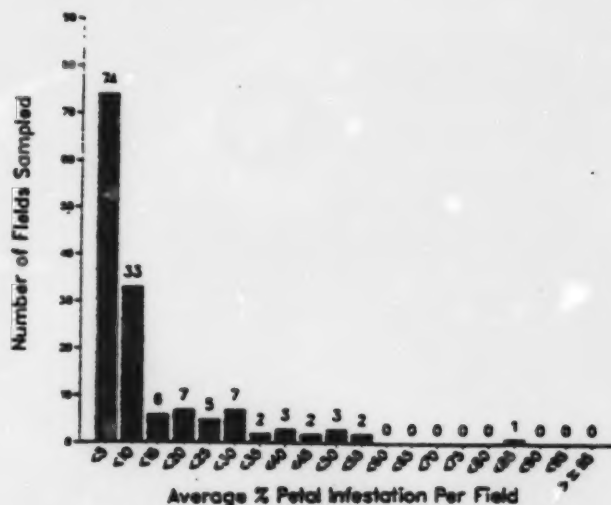
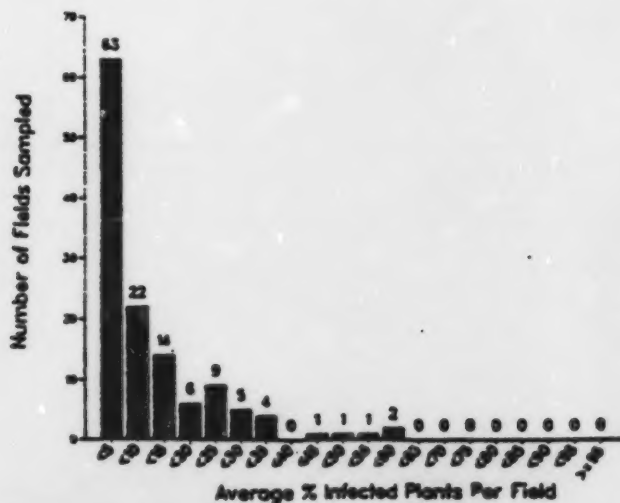


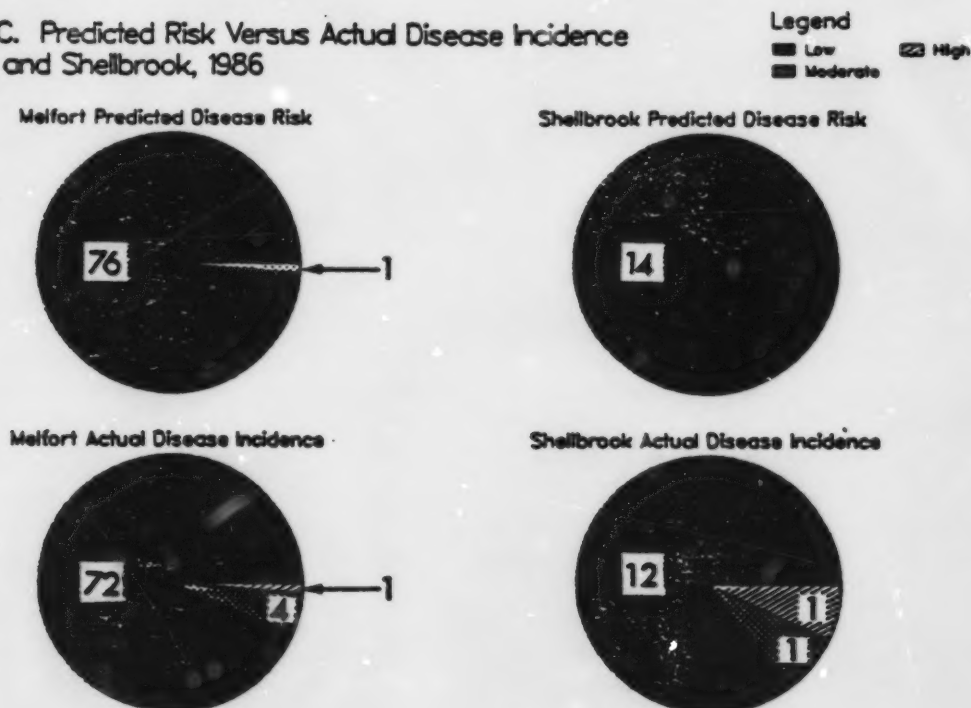
Figure B. Observed Levels of Stem Rot infection, 1986



## (II) PREDICTED RISK VERSUS ACTUAL DISEASE INCIDENCE

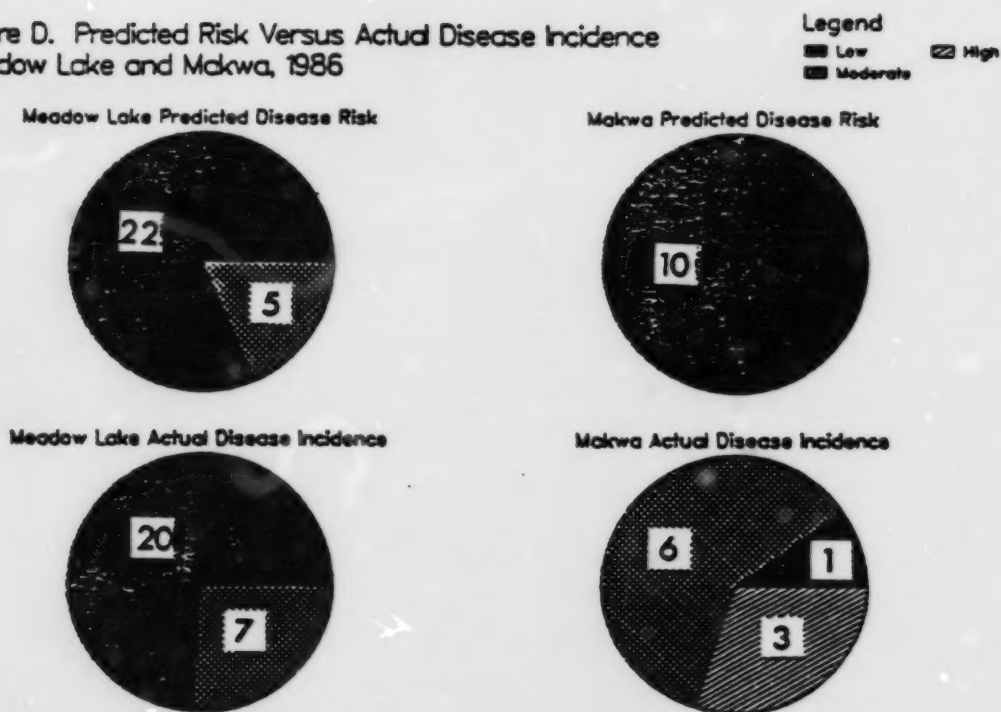
Disease risk can be expressed as low, moderate, or high depending on the level of petal infestation (see attached brochure). Of the 77 fields assessed in August in the Melfort-Carrot River area, 76 were predicted to be at low disease risk, one to be at moderate risk, and none at high risk (Figure C). When disease incidence was assessed, 72 fields had low disease levels, four had moderate and one had high (Figure C). In the Shellbrook area all of the 14 fields tested were predicted to be at low disease risk (Figure C). In late August, 12 of the 14 fields had low disease incidence, one had moderate, and one had high (Figure C). Slightly more fields had moderate and high disease levels than predicted by the level of petal infestation in both the Melfort-Carrot River and Shellbrook areas.

Figure C. Predicted Risk Versus Actual Disease Incidence  
Melfort and Shellbrook, 1986



For the Meadow Lake area 22 of the 27 fields were predicted to be at low disease risk, five to be at moderate and none at high risk (Figure D). When disease was assessed 20 of the fields had low and seven had moderate disease levels (Figure D). As in the Melfort-Carrot River and Shellbrook areas, in a small number of fields the level of disease was underestimated by the level of petal infestation. For the 10 fields in the Makwa area all were predicted to be at low disease risk (Figure D). However, when disease incidence was assessed only one field had a low disease level, six had moderate, and three had high levels (Figure D). While our disease risk predictions for the other areas were fairly accurate, those for the Makwa area underestimated the level of disease in nine of the ten fields tested.

Figure D. Predicted Risk Versus Actual Disease Incidence  
Meadow Lake and Makwa, 1986





Another way of looking at the results is by grouping them according to the number of fields where the disease level was correctly predicted, and the numbers of fields where disease was underestimated or overestimated. Results are expressed in this manner in Table I.

TABLE I. PREDICTED RISK VS. ACTUAL DISEASE INCIDENCE, SCLEROTINIA PROJECT 198

|                     | NUMBER OF FIELDS |            |             |       |       |
|---------------------|------------------|------------|-------------|-------|-------|
|                     | MELFORT          | SHELLBROOK | MEADOW LAKE | MAKVA | OVERA |
| UNDERESTIMATED      | 4                | 2          | 5           | 9     | 20    |
| CORRECTLY ESTIMATED | 72               | 12         | 19          | 1     | 104   |
| OVERESTIMATED       | 1                | 0          | 3           | 0     | 4     |

From Table I it is evident we were able to correctly identify the disease risk for the majority of fields, which is not surprising considering moisture conditions during the summer. However, for a few fields we overestimated the disease risk, and for somewhat more (especially at Makva) the risk was underestimated.

#### WHY WERE SOME PREDICTIONS INCORRECT?

##### (I) EFFECTS OF WEATHER ON DISEASE DEVELOPMENT

Moisture conditions were generally poor in both the Melfort-Carrot River and Shellbrook areas during June and the first week of July. Approximately 25mm of rain fell during June in both areas. Rainfall remained relatively low until the second week in July and then increased. The increase probably produced conditions more conducive to spore production, plant infection, and disease development and may have prolonged the period of flowering. These factors may have resulted in somewhat higher disease levels than predicted in those areas.

Moisture conditions in the Makva area were good throughout June and July, and this was reflected by higher disease levels. However, as indicated previously, the level of disease was underestimated in 9 of the 10 fields tested. This underestimation may be related

slightly lower rainfall during late June and early July, which caused lower levels of petal infestation at the time of sampling. Large amounts of rainfall later in July may have greatly enhanced disease development in the same manner as in the Melfort-Carrot River and Shellbrook areas. Although this may help to explain why disease risk was underestimated in the Makva area, moisture throughout June was still relatively favorable compared with other areas. Therefore other possible explanations for underestimation need to be considered.

## (II) EFFECTS OF WEATHER ON DISEASE RISK ESTIMATES

Several of the fields in the Makva area were sampled while it was raining or immediately afterwards. European researchers have suggested that moderate to heavy rainfall prevents spore release and washes spores off plant surfaces, such as petals. Thus, if petals are collected during moderate to heavy rainfall levels of petal infestation may be unrealistically low.

## (III) EFFECTS OF LODGING ON DISEASE INCIDENCE

When crops lodge, direct plant-to-plant disease spread takes place, thereby increasing overall disease levels. In some fields in 1986 sampling sites were located in low spots and other areas where localized lodging occurred. The disease risk predicted from petal infestation was probably accurately reflected by disease incidence in the field at large. However, disease incidence at the specific sampling sites was abnormally high.

## (IV) OVERESTIMATION

In four fields in 1986 the level of disease was overestimated; three were in the Meadow Lake area and one in the Melfort-Carrot River area. The Melfort field was sampled late in July when the crop was at full bloom. However, the Meadow Lake fields were sampled at the correct stage, ie. at early bloom. All four fields were predicted to be at moderate disease risk, but actual disease incidence ranged from nine to 19%. It is perhaps significant that the levels of petal infestation in all four cases were on the borderline between moderate and low disease risk.

### SAMPLE SIZE EXPERIMENTS

In addition to testing samples from growers fields, three experiments were set up in 1986 to investigate the scale of sampling required to obtain accurate estimates of the level of petal infestation. Two were near Melfort and one in the Meadow Lake area. The results support data from 1985 and indicate that approximately five sites per field with 40 petals collected per site is sufficient. The number of sites might have to be increased for large fields over 100 acres.

### CONCLUSIONS AND FUTURE STUDIES

Results from 1986 illustrate the importance of moisture to the disease prediction system. Disease risk for a particular field can change throughout the bloom period depending on rainfall. Although it is very difficult to forecast future weather conditions, our approach to disease prediction is still promising. More careful monitoring of rain and dew before and after sampling should help to alleviate some of the problems associated with changing moisture conditions. Also short term weather forecasts from Environment Canada may be integrated into the prediction system.

Fine tuning of the sampling procedures is required. The time of day and conditions under which samples should be collected needs to be investigated. Another important aspect that should be studied further is the plant growth stage at which samples are collected. Currently farmers are asked to collect samples at early bloom. However, results from 1985 and 1986 suggest that the level of petal infestation, and therefore disease risk, can change throughout the bloom period. It may be possible to collect samples at later growth stages and obtain test results while chemical control is still effective.

We think our approach to disease forecasting is promising, even with the limitations imposed by changing weather conditions. Using the level of petal infestation in conjunction with traditional methods can potentially provide a better method of forecasting sclerotinia stem rot. We encourage you to participate in the Sclerotinia Project in 1987 and look forward to seeing you this summer.

#### ACKNOWLEDGEMENTS

This project is supported by the Canola Council of Canada, the Agriculture Development Fund, the agrichemical industry and the Agriculture Canada Research Station at Melfort. The assistance of Harold Amundson, Dave Cubbon and all farmers who collected samples, allowed us to use their fields for tests, and monitored rainfall for us is gratefully acknowledged.



# SCLEROTINIA PROJECT

## Year 3

Department of Biology  
University of Saskatchewan  
Saskatoon, SK S7N 0W0

The goal of the project is to improve the ability to forecast the severity of sclerotinia stem rot in canola crops. This will help to rationalize the use of fungicides for control. The method of forecasting is based on testing canola petals for the presence of sclerotinia spores when the crop is at early bloom. The project is supported by the Canola Council of Canada, the Agriculture Development Fund and the Agriculture Canada Research Station at Melfort.

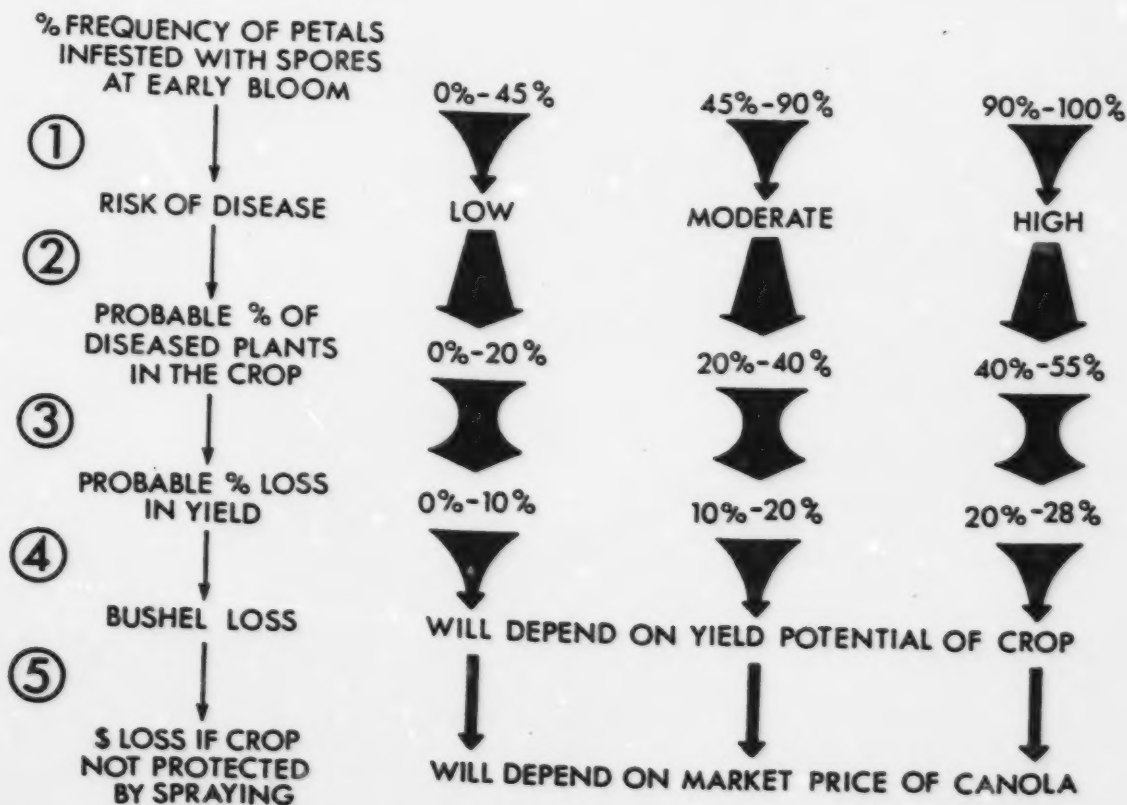
### WE STILL WANT YOUR HELP

The Sclerotinia project is in its third year. Until now it has depended mainly on growers bringing samples of petals from their crops to us at a central facility. We still want you to provide such samples in order to provide a data base for continued assessment of this method of forecasting. However, the project is also moving in new directions. For example, we are working with a small group of growers who will be setting up their own petal test. This will serve to determine if the test is suitable for on-the-farm use. Eventually we hope to develop a kit that growers may obtain for themselves. In 1987 we shall also be studying the effects that weather conditions and time of collection have on the results given by the petal test. It is important that misleading forecasts are not issued because petals are collected at inappropriate times. Finally, the project is being extended from the primary study area around Melfort into the Shellbrook and Meadow Lake areas. Partly because of drought in the northeast, we did obtain some samples from those areas in 1986 on an emergency basis. Now we hope to welcome growers in these areas to the project on a regular basis, thanks to the help of local ag. reps.

# USING PETAL INFESTATION TO FORECAST SCLEROTINIA AND DETERMINE YIELD LOSSES

The concept of petal testing to forecast stem rot is based on the unique disease cycle of the sclerotinia fungus. Infectious spores of sclerotinia must be in contact with petals or other flower parts in order to penetrate the plant and cause disease. Consequently, the amount of disease that develops in a crop will reflect, among other things, the percentage of petals which carry spores. Testing petals for the presence of sclerotinia spores at early bloom can thus provide a guide as to whether the crop may benefit from being sprayed. Two major advantages of petal testing over other forecasting methods are that (a) the test can be done on an individual field basis and (b) it takes account of spores blowing into a canola crop from sources external to the field. However, as with all other forecasting systems the prediction and the actual disease outcome may differ if abnormal weather conditions occur from full bloom onwards.

Previous studies in western Canada suggest that, under average conditions, the relationships depicted in the chart below apply in canola crops. You may wish to use parts of this chart to help decide if spraying might pay off in your crop. However, remember that step 2 is the most variable because it depends a great deal on plant stand and on weather conditions after full bloom. Thus, if hot dry weather occurs in late July, the actual disease incidence and % yield loss in a crop will be less than forecast. Conversely, if unusually cool wet weather persists during late bloom, even fields forecast to be at low risk may develop moderate amounts of stem rot.



## HOW TO PARTICIPATE

The success of the project depends to a considerable extent on grovers helping us by providing petal samples for testing when their crops are in early bloom. It works like this: When your crop is at the correct growth stage (see page 4), collect 5 - 10 flowering shoots at each of 4, or preferably 5 sites down one side of your field (see enclosed sheet). Keep the samples in separate clean, labelled plastic bags and take them to the lab as quickly as possible. At Melfort the lab is located at the Agriculture Canada Research Station. In Shellbrook and Meadow Lake take the samples to the ag. rep. offices. We will do the petal test and phone to give you the results 3 1/2 days later. You can then consult the chart on page 2 to help you evaluate the potential yield loss in your crop.

Our lab at the Melfort Research Station is easy to find. It is located in the old Horticulture Building. Just follow the signs saying "Sclerotinia Project". The lab will be open 7 days a week. From Monday to Saturday it will be open from 7.30 a.m. to 6.30 p.m. and on Sundays from 1.30 p.m. to 6.30 p.m. Call 752-3070 for more information. After hours leave a message on the answering machine and we will call you back the next morning. In Shellbrook and Meadow Lake services will be available during normal office hours.

### WIN ENOUGH FUNGICIDE TO SPRAY 20 ACRES (RETAIL VALUE \$300)!

In July when canola crops are flowering we shall hold four draws at about 5-day intervals. The names entered in these draws will be those of grovers who have delivered samples for the project since the previous draw. Each winner will receive enough fungicide to treat 20 acres of canola. These prizes have been kindly donated by the manufacturers of Benlate and Rovral. The draws will be independently supervised and the judge's decision will be final.

## THREE WAYS TO CHOOSE THE CORRECT GROWTH STAGE FOR SAMPLING

(a) Your canola should be at stage 4.2 in the growth stage key shown on the right. This key is identical to that in Chapter 3 of the Canola Grower's Manual.

(b) The crop should be at what many growers call 20% bloom. (See the illustration below.) This is when an average of about 12-15 flowers are open on the main stem. With Polish rapeseed use the high end of this range. With Argentine varieties, use the low end.

(c) The crop should have started showing yellow blossoms about 5-6 days earlier. Do not include wild mustard blossoms in this assessment. Also ignore volunteer Polish canola in fields of Argentine. If the weather is very warm, the period could be at least 1 day shorter.

### CANOLA GROWTH STAGES

0. Pre-emergence
1. Seedling
2. Rosette
3. Bud
4. Flower
  - 4.1 First flower open
  - 4.2 Many flowers open, lower pods elongating.
  - 4.3 Lower pods starting to fill.
  - 4.4 Flowering complete, seed enlarging in lower pods.
5. Ripening





NEW PROCEDURES FOR SAMPLING

1) Collect canola blossoms at four, or preferably five sites in each field.

2) Do not collect blossoms too early in the day. It is recommended not to collect before 9.00 a.m. Also, do not collect blossoms during rainfall, for a period of 4 hours after a heavy rain or for a period of 2 hours after a light rain.

3) There is no need to stake each site where you collect blossom samples. However, make sure that the sites are separated from each other by at least 50 yards. Also, be ready to draw a rough map showing where the sites were in the field when you deliver the samples to the lab. When we assess disease incidence in your field in August we shall take measurements in the same general area that you collected samples, but not at exactly the same sites.

4) We shall provide you with one numbered stake for each field in which samples were collected. Please place it in a readily visible place on the edge of the field.

5) Walk at least 20-30 yards into the crop at each sampling site. Avoid collecting samples from low areas in fields, areas close to trees, weedy areas, headlands which may be double-seeded and anywhere that you know the crop is especially susceptible to lodging. The results of a petal test in such places may be fairly typical of the whole field. However, the amount of disease is likely to differ from the rest of the field and be higher or lower than would normally be forecast by the petal test. The petal test should provide the most accurate forecast for open areas of fields with average stands. When the crop is very light or weedy the test will generally overestimate disease incidence. In dense stands which lodge later in the season disease incidence will be more than forecast by the petal test.

6) At each site, cut the tops of 5 to 10 flowering shoots so that we will have at least 50 open yellow flowers from each site. Place the tops from each site in a clean (preferably new) plastic bag and label it appropriately. Please use a fairly large bag as it is important not to squash the petals together too much. Close the bags but do not seal them too tightly. At all times keep them as clean as possible, particularly away from soil. When you have collected samples from a field take the bags to the lab. Do not leave the bags in the sun and if possible take them to the lab no more than two hours after collection. If in any doubt about the sampling procedure, please phone us at 752-3070.

7) Remember that weather conditions after you have collected the petals for testing can influence the actual disease incidence in your field. Bear this in mind when you evaluate the results of the petal test that we give you.

For your files.

Appendix A (vi)

Kelly  
March 18/88

SCLEROTINIA PROJECT  
UNIVERSITY OF SASKATCHEWAN  
DEPARTMENT OF BIOLOGY  
SASKATOON, SASK.  
S7N 0W0

GENERAL RESULTS 1987

We wish to thank those growers who participated in the 1987 project. The number of participants was rather small, perhaps due to poor moisture conditions, resulting in a low risk of disease for the Melfort area. However, the data that were collected helped to confirm the 1985 and 1986 results and suggested a number of avenues for further research. Please read through this report and the attached page(s) which apply to your own field(s). If you have any questions send us a letter or call us at 966-4410 (Robin Morrall) or 966-4425 (Kelly Turkington).

(1) DISEASE FORECASTING

The lab in 1987 was open from June 25 to July 22 and during this period petals from 58 crops were tested. However, the majority of the crops were part of a study by David Kaminski, who investigated the potential of home petal testing by growers. Of the 58 crops tested in June and July only 54 were assessed for disease in August.

Results from 1987 were very similar to those in 1986. Lack of moisture in June restricted the levels of petal infestation and disease. Levels of petal infestation ranged from 0 to 40.0% with an average of 6.97%, while disease levels ranged from 0 to 11.4% with an average of 1.49%.

According to the brochure sent to you in June 1987, disease risk can be expressed as low, moderate or high depending on the level of petal infestation. In 1987 all crops were forecast to be at low disease risk. When disease was assessed all crops had low disease levels. This is not surprising considering the poor moisture conditions that occurred in June and early July and it certainly makes our percentage success look good!

(2) INTENSIVE EXPERIMENTS

In six crops petal infestation levels were monitored on a daily

basis throughout the flowering period and disease was assessed later in August. Levels of petal infestation were found to change throughout the flowering period as moisture conditions changed. Moderate disease levels were found when moderate levels of petal infestation and conducive moisture conditions occurred from full to late-bloom.

Disease forecasts based on petal infestation at early-bloom in the six crops were mostly correct. Four of the six crops were forecast to be at low risk and had low disease levels. A single crop was found to be at moderate risk and had a moderate level of disease in August. For the last crop the level of petal infestation was very low at early-bloom and thus was forecast to be at low disease risk. However, in August a moderate level of disease was found. Improved moisture conditions produced higher levels of petal infestation and more favorable conditions for infection at full to late-bloom compared to early-bloom.

### (3) CONCLUSIONS

Results from 1987 support those from 1985 and 1986. Relatively accurate forecasts of disease risk can be obtained by assessing the level of petal infestation at early-bloom. However, other factors such as canopy density and changing moisture conditions can also influence the final disease outcome and need to be taken into account in forecasting.

Results from the 1987 intensive experiments suggest that testing petals more than once during the flowering period may provide a more accurate forecast of disease risk. This will be especially important when moisture conditions change during flowering. Recent work suggests that this approach could still be integrated with effective chemical control.

In the future the service of petal testing provided by our lab will be scaled down. We will still do petal testing when requested to do so. However, we encourage you to test your own petals and will provide all the materials needed for this. Once the test is set up you can bring the materials to our lab any time in the following three days and we will read the results for you. David Kaminski's project last summer clearly demonstrated that growers of all ages and technical backgrounds can easily set the petal test up themselves.

The primary focus of our field studies in 1988 will be more experimentally oriented. The influence of changing moisture conditions and changing petal infestation levels on final disease development will be studied further. Factors such as canopy density and lodging, which influence disease development will also be investigated.

We encourage you to keep an active interest in the research we are conducting. Your assistance in the past, present and future is gratefully acknowledged! Hope to see you again in 1988!

## SCLEROTINIA PROJECT

Year 4

The purpose of this project is to improve methods of forecasting sclerotinia stem rot of canola and help to rationalize the use of fungicides for control. This is especially important when the price of canola is rising and more growers may contemplate spraying their crops. Over the past few years we have developed a technique to estimate disease risk based on testing canola petals for the presence of sclerotinia spores. Changes in disease risk due to changing weather conditions during the bloom period can be detected by repeating the test two or three times. Studies in 1987 showed that the test can be quite readily set up on the farm by growers themselves. Ultimately we hope that a complete package will be available for home use so that growers may test petals, evaluate the results and use them to make decisions about fungicide usage independently.

## MAY WE HELP YOU?

A major thrust of our research in 1988 will be on fine-tuning the disease forecasting system. We shall be conducting experiments to clarify the effects of crop density and of changes in weather and spore concentrations on the accuracy of forecasts. However, we invite growers to continue to use our services to assess disease risk in their crops. The preferred way to do this would be for us to provide you with a free petal testing kit. The kit contains instructions on how to set up the test, including a 5 min. instructional video, if you wish. After you set the test up you would have 3 days to take or send the materials to our lab so that we could read the results for you. A less desirable alternative would be for you to collect petals and take them immediately afterwards to the lab where we will set the test up. Phone 752-3070 to obtain free petal test kits or for further information. Please read the instructions on the enclosed sheet on how to collect petal samples.

The best time to start petal testing is about 5 days after the first yellow blossoms appear in the crop (growth stage 4.2 on the scale below). This will provide time to decide if spraying might be worthwhile. Depending on the results of this test and the value of the crop a subsequent test might be advisable.

## Canola Growth Stages

0. Pre-emergence
1. Seedling
2. Rosette
3. Bud
4. Flower
  - 4.1 First flower open
  - 4.2 Many flowers open, lower pods elongating
  - 4.3 Lower pods starting to fill
  - 4.4 Flowering complete, seed enlarging in lower pods.
5. Ripening

START PETAL TESTING AT EARLY BLOOM





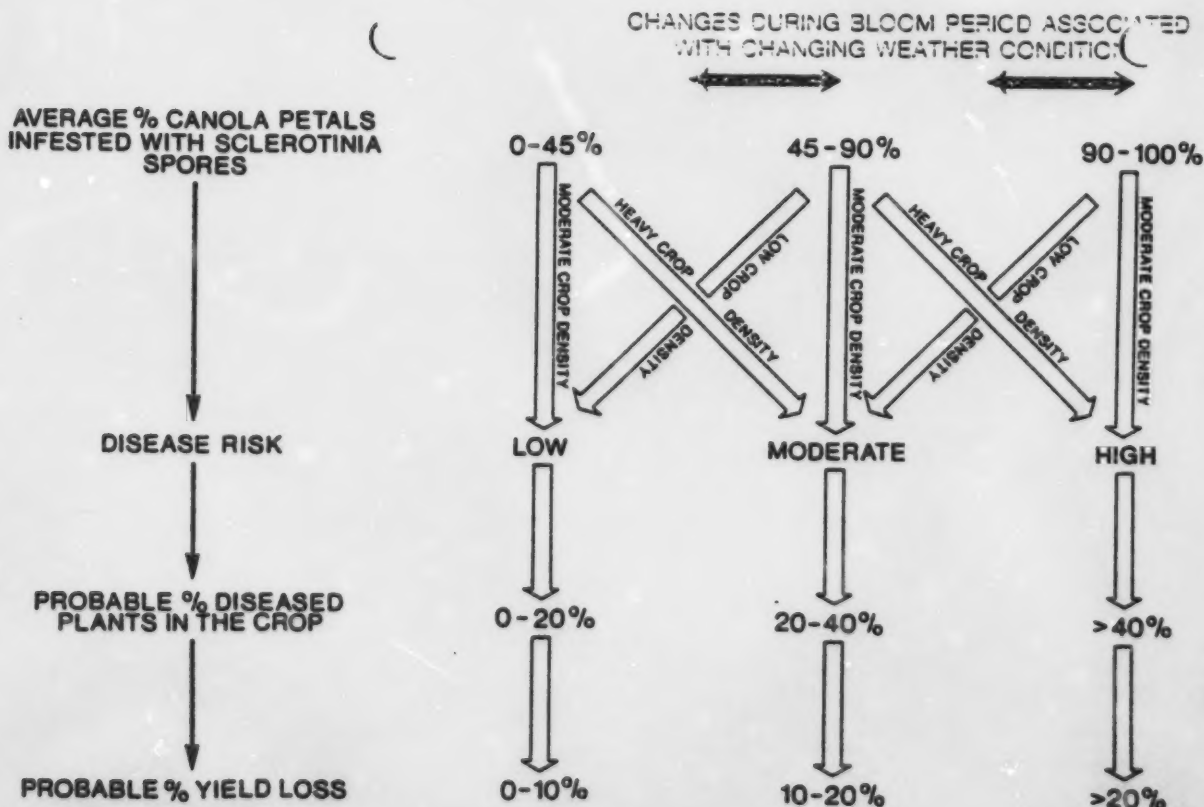
# SPONSORSHIP

The Sclerotinia Project is a project of faculty and students of the Department of Biology, University of Saskatchewan, Saskatoon, S7N 0W0. The financial and other support of the Canola Council of Canada, the Agriculture Development Fund (Saskatchewan Agriculture) and the Agriculture Canada Research Station at Melfort are gratefully acknowledged.

## USING PETAL INFESTATION TO FORECAST SCLEROTINIA AND DETERMINE YIELD LOSSES

The concept of petal testing to forecast sclerotinia stem rot is based on the unique disease cycle of the sclerotinia fungus. Infectious spores of sclerotinia must be in contact with petals or other flower parts in order to penetrate the plant and cause disease. Hence, the incidence of stem rot in the crop will partly reflect the percentage of flower parts which were carrying spores. However, crop density which affects microclimate in the crop, as well as weather conditions will play a role in determining disease incidence. Changing weather during the bloom period is especially important because it may alter spore concentrations in the atmosphere and on flower parts and cause the disease risk to increase or decrease.

The general relationships of petal infestation and disease incidence as we currently understand them are illustrated in the chart on the page opposite. The two major advantages of petal testing over other forecasting methods are (a) the test can be done on an individual field basis rather than forecasting on a regional basis, and (b) the test takes account of spores blowing into canola crops from sources external to the field.



PROCEDURES FOR COLLECTING PETALS FOR TESTING IN 1988

- 1) Collect for the first time at early bloom (4-6 days after the crop starts to flower).
- 2) Collect at four, or preferably five sites in each field.
- 3) Do not collect blossoms too early in the day. The ideal time is between noon and 5 p.m. Also, do not collect during rainfall, for a period of 4 hours after a heavy rain or for a period of 2 hours after a light rain. Collecting at inappropriate times may result in underestimates of disease risk.
- 4) Make sure that the collection sites are separated from each other by at least 50 yards. Also, be ready to draw a rough map showing where the sites were in the field when you deliver the petal samples or petri dishes (if you are setting up your own test) to the lab. If we have time to assess disease incidence in your field in August we shall take measurements in the same general area that you collected samples. We can provide you with a tall numbered stake for each field in which samples were collected. Please place it in a readily visible place on the edge of the field in case we check your field in August.
- 5) Walk at least 20-30 yards into the crop at each sampling site. Avoid collecting samples from low or weedy areas, headlands which may be double-seeded, areas close to trees, and anywhere that you know the crop is especially susceptible to lodging. Even if the results of a petal test in such places may be fairly representative of the whole field, disease incidence later on will not be. The petal test should provide the most accurate forecast for open areas of fields with average stands.
- 6) At each site, cut the tops of 8 to 10 flowering shoots so that there will be at least 50 open yellow flowers from each site. Place the tops from each site in a clean (preferably new) plastic bag and label it appropriately. Please use a fairly large bag as it is important not to crush the petals together too much. Close the bags but do not seal them too tightly. At all times keep them as clean as possible, particularly away from soil. When you have collected samples from a field make sure that they are processed or delivered to our lab within 2 hours.
- 7) For information on where lab facilities are available please phone one of the following numbers: 752-3070 (Melfort); 966-4410 (Saskatoon); 236-4441 (Meadow Lake); 867-9931 (Outlook).
- 8) The results of the petal test will be available 3 1/2 days after it is set up. Depending on the results of the test conducted at early bloom and weather conditions over the next few days, you may wish to repeat the test to determine if the disease risk has changed.
- 9) If you spray your crop with a fungicide to control sclerotinia, please let us know and/or leave a non-sprayed check strip for comparison.

Appendix B. Abstract of thesis by T.K. Turkington. (1988)

## CANOLA DISEASES AND CONTROL

Groverers in E. central Saskatchewan are familiar with the two major diseases of canola: sclerotinia stem rot and blackleg. A high level of control of blackleg can be achieved by adequate crop rotation, but the same is not always true with sclerotinia. Spores of sclerotinia blow into canola crops from distant sources and, given the right weather conditions, may initiate severe infestations.

Two fungicides are registered against sclerotinia, but to achieve optimum control the crop should be sprayed before full bloom, i.e. before the disease becomes visible. The fungicides work well, but spraying costs about \$20.00 an acre for chemical at the recommended rate, plus application costs. Thus, grovers would like to have a reliable method of forecasting disease when the crop is in early bloom, so as to help them decide whether to invest in fungicide application.

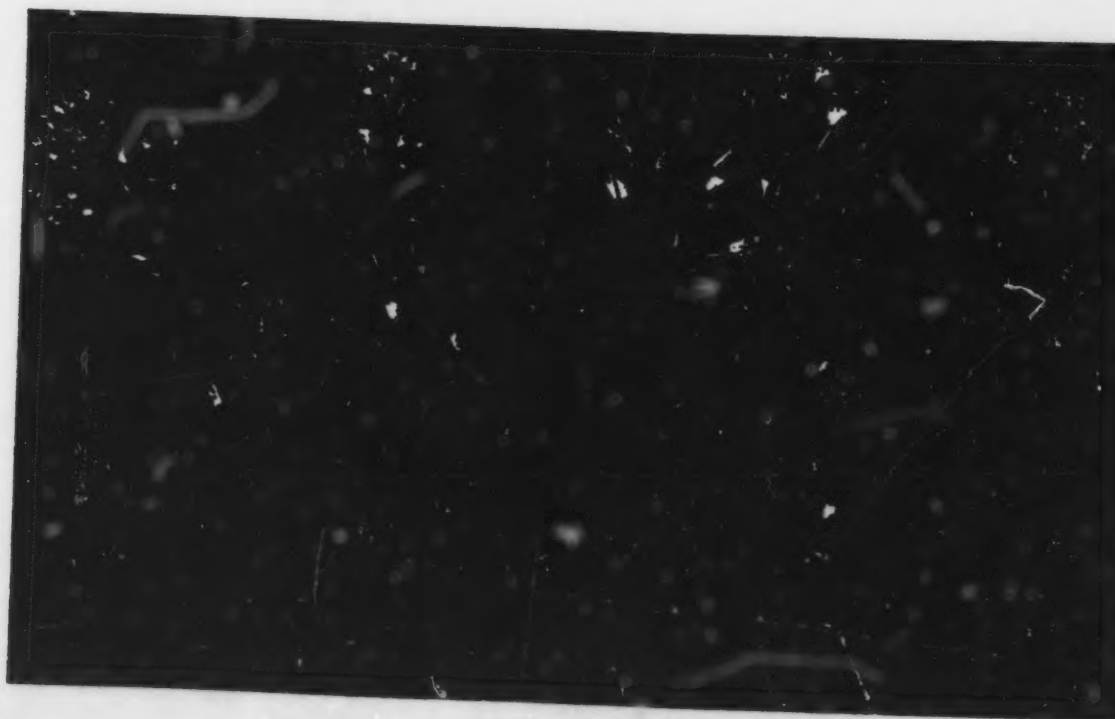


## THREE WAYS TO CHOOSE THE CORRECT GROWTH STAGE FOR SAMPLING

- (a) Your canola should be at stage 4.2 in the growth stages key shown on the right hand side. This key is identical to that in Chapter 3 of the Canola Grover's Manual.
- (b) The crop should be at what many growers call 20% bloom. (See the illustration below.) This is when an average of about 12-15 flowers are open on the main stem. With Polish rapeseed use the high end of this range. With Argentine varieties, use the low end.
- (c) The crop should have started showing yellow blossoms about 5-6 days earlier. Do not include wild mustard blossoms in this assessment. If the weather is very warm, the period could be at least 1 day shorter.

### CANOLA GROWTH STAGES

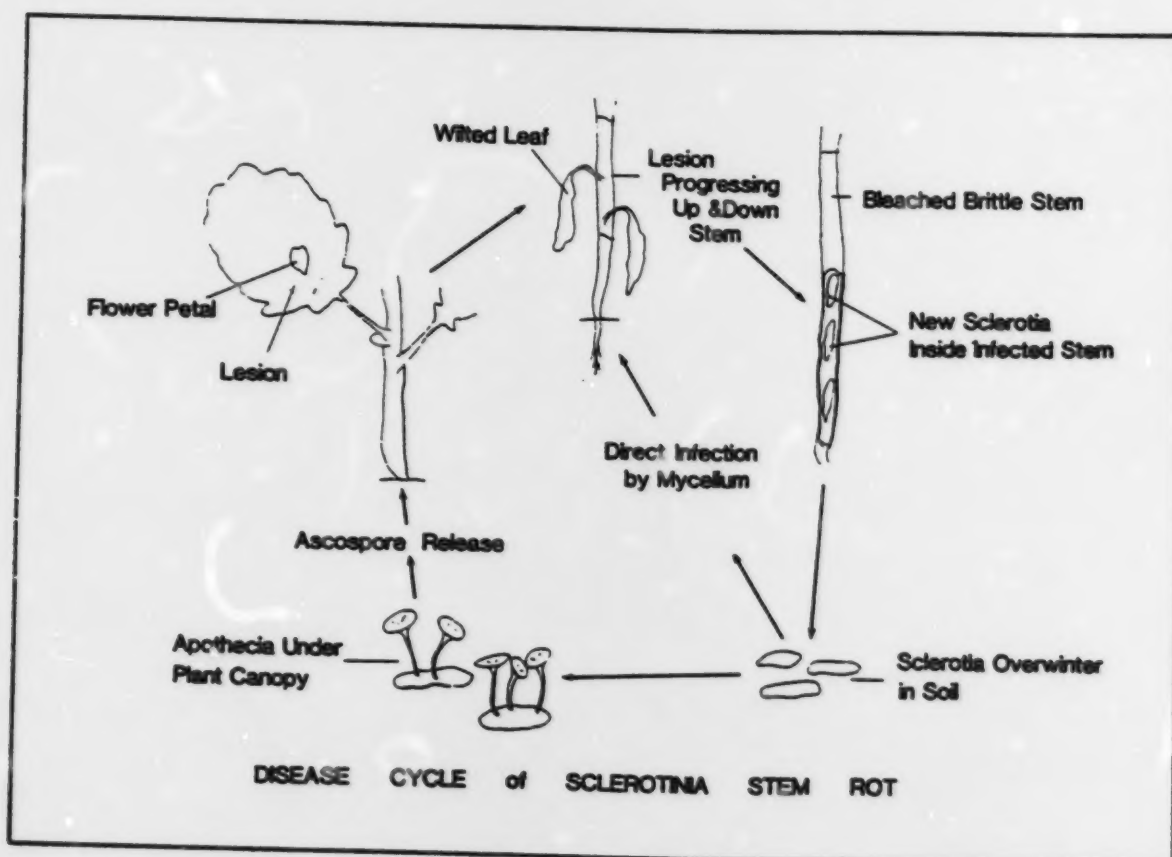
- 0. Pre-emergence
- 1. Seedling
- 2. Rosette
- 3. Bud
- 4. Flower
  - 4.1 First flower open
  - 4.2 Many flowers open, lower pods elongating.
  - 4.3 Lower pods starting to fill.
  - 4.4 Flowering complete, seed enlarging in lower pods.
- 5. Ripening



## PREDICTING SCLEROTINIA BASED ON PETAL INFESTATION

Our pilot project in the Melfort area is now in its second year. It is designed to learn how to forecast sclerotinia stem rot on the basis of the level of infestation of canola petals with spores of the sclerotinia fungus.

The project depends on growers lending us a helping hand by bringing samples to our lab when their crops are in early bloom. It works like this: When the crop is at the correct growth stage, you collect 5 - 10 flowering shoots at each of 4 sites down one side of your field (see enclosed sheet). Keep the samples in 4 separate clean, labelled, plastic bags and take them to our lab at the Melfort Research Station as quickly as possible. We will test the petals and let you know the average frequency of infestation with sclerotinia. You can then consult the chart in this brochure to help you evaluate the risk of yield loss in your crop.



## ADVANTAGES OF FORECASTING DISEASE BASED ON PETAL INFESTATION

This method of forecasting sclerotinia is generally a step ahead of predictions based on finding apothecia in your crops, past history of sclerotinia in the area and crop density. The main biological advantage is that it accounts for spores blowing into the crop from unknown external sources. Thus, the effects of weather conditions on release of spores by apothecia are partly compensated for. The method has another advantage. It is simpler and cleaner than crawling around on your hands and knees looking for apothecia!

Appendix B

USING ASCOSPORE INFESTATION OF PETALS TO  
FORECAST SCLEROTINIA STEM ROT OF RAPESEED

A Thesis

Submitted to the College of Graduate Studies and Research  
in Partial Fulfilment of the Requirements

for the Degree of

Master of Science

in the

Department of Biology

by

Thomas Kelly Turkington

Saskatoon, Saskatchewan

January, 1988

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## Abstract

The potential of using the percentage of ascospore infested rapeseed petals to provide a quantitative forecast of the incidence of sclerotinia stem rot in rapeseed was studied in several areas of Saskatchewan in 1985 and 1986. A pilot project in which farmers collected petal samples was set up to study the commercial feasibility of such an approach. Farmers normally collected rapeseed petals during early bloom and were then given a disease risk forecast based on the percentage of infested petals determined by a laboratory agar plate test. In crops that had been sampled disease incidence was determined later in the growing season. Intensive field studies were also conducted to investigate the effect of sample size on estimates of petal infestation and disease incidence. Finally, laboratory studies were conducted to find a growth medium for the agar plate test which did not restrict the growth of Sclerotinia sclerotiorum, allowed rapid identification of the fungus and assured good protection from bacterial contamination.

The results indicated that disease forecasting based on petal infestation would be feasible on a commercial scale, with farmers collecting petal samples. Forecasts were relatively accurate when the disease risk was low. However, problems occurred in identifying crops at moderate and high disease risk. This was attributed to moisture conditions and inoculum levels changing during flowering. It is suggested that repeated petal sampling during flowering might alleviate this problem. Crop canopy density appeared to be an important factor affecting the relationship of petal infestation with disease incidence. Disease incidence was higher per unit of petal infestation in crops with dense canopies.



The intensive field studies indicated that a sample size of five to six sites per crop, with 40 petals tested per site could be used to estimate the mean percentage of petal infestation in the crop with a standard error of 5%. Based on results from laboratory experiments the growth medium for plating petals was changed slightly from 1985 to 1986. This change allowed the identification of S. sclerotiorum after 3-4 days in 1986 compared to 5 days in 1985.

The possibility of incorporating prevailing moisture conditions, canopy density and changing inoculum levels in a future forecasting system is discussed.

Appendix C. Paper by T.K. Turkington et al. (1988)

## Sample sizes in relation to forecasting sclerotinia stem rot of canola

T.K. Turkington, R.A.A. Morrall, and R.J. Baker

Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, and  
(R.J.B.) Crop Development Centre, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0.

Accepted for publication 1988 03 03

Five experiments were conducted in commercial crops of canola in 1985 and 1986. The percentages of petals infested with *Sclerotinia sclerotiorum* were determined at specific sites in each field by plating on agar, using four petals per petri dish. A total of 100 petals per site were plated in 1985 and 40 per site in 1986. A one-way ANOVA on a single dish basis, with sites as the primary unit, was used to divide total variation into variation among sites and among dishes within sites for each experiment. Using a procedure for two-stage sampling, the effect of various sample sizes on accuracy of the measurement of mean % of petals infested was determined. Results indicated that sampling at five to six sites per field, with 40 petals collected per site could be used to estimate the mean % of petals infested with a standard error of about 5% in most fields. Disease incidence was assessed at each site in August before the crops were swathed. The data were used to determine the sample size required to estimate the mean disease incidence with three specified levels of precision ( $\pm 2.5$ , 5.0, 10.0%) at  $P = 0.05$  in each experiment. The required sample size varied greatly among experiments and appeared to be related to stand uniformity. When lodging occurred in parts of the crop, variability in disease incidence among sites was relatively high.

Turkington, T.K., R.A.A. Morrall, and R.J. Baker. 1988. Sample sizes in relation to forecasting sclerotinia stem rot of canola. Can. J. Plant Pathol. 10: 159-165.

En 1985 et 1986 on a fait cinq expériences dans des cultures commerciales de colza. Le pourcentage des pétales contaminés par *Sclerotinia sclerotiorum* a été déterminé à plusieurs sites pour chaque culture, par l'isolement sur un milieu gélosé. L'isolement a été effectué en mettant quatre pétales dans chaque boîte de Pétri. Le nombre de pétales testés par site a été de 100 en 1985 et 40 en 1986. Le résultat de chaque boîte de Pétri a été noté séparément. Pour chaque expérience, une analyse de variance à un niveau nous a permis de diviser la variation totale du pourcentage de contamination entre la variation due aux sites et celle due aux échantillons (boîtes de Pétri) à l'intérieur d'un site. Selon une méthode d'échantillonnage à deux étapes, l'effet de la taille de l'échantillon sur la précision d'estimation du pourcentage des pétales contaminés a été déterminé. Généralement, l'utilisation de 40 pétales à chacun de cinq ou six sites dans un même champ a permis l'estimation du pourcentage moyen avec un écart type de 5%. L'incidence de la maladie a été déterminée à chaque site en août, peu de temps avant la récolte. Dans chaque expérience, les données ont été utilisées afin de calculer le nombre de sites nécessaire pour déterminer l'incidence moyenne de la maladie aux niveaux de précision de  $\pm 2.5$ , 5.0, et 10.0% ( $P = 0.05$ ). Le nombre a varié beaucoup en fonction de l'expérience, probablement dû au degré d'homogénéité de la culture dans un même champ. Lorsque la verse était présente dans certaines parties d'une culture, la variation parmi les sites de l'incidence de la maladie a été relativement élevée.

The importance of a saprophytic food base for ascospore germination in the life cycle of *Sclerotinia sclerotiorum* (Lib.) de Bary on various host plants is well known (7,8,9). Stem rot infections in canola (rapeseed) (*Brassica campestris* L. and *B. napus* L.) are initiated where fallen petals have lodged on the plant (11). However, Lamarque (5) and Kapoor et al. (4) have demonstrated that petals may be contaminated by ascospores and even colonized by hyphae when still *in situ* in the inflorescence.

The presence of inoculum of *S. sclerotiorum* on various parts of the canola plant was studied in 1983 and 1984 by Gugel et al. (2). They demonstrated a quantitative relationship between infested petals and disease incidence and suggested that the relationship might be exploited to assist growers considering fungicide application for disease control. Subsequent work in our laboratory has been directed towards developing a disease forecasting system in which measurements of

inoculum on petals are used to supplement existing nonquantitative criteria (11). One of the questions addressed has been the scale of sampling needed in commercial crops to obtain reliable results. The present study was designed to investigate how estimates of percentage infestation of petals with *S. sclerotiorum* are affected by the size and number of samples collected. A secondary objective was to study how number of sampling sites affects estimates of disease incidence.

## Materials and methods

**Petal infestation. 1985** — Two experiments were established in commercial fields of *Brassica napus* cv. Westar in the Melfort area of east-central Saskatchewan. The fields were chosen because both had good, uniform, relatively weed-free stands and the owners did not intend to spray for stem rot control and were willing to permit destructive sampling. In Experiment 1 apothecia were observed in the field.

Experiment 1 consisted of a 200 × 50 m area, divided into 100 10 × 10 m sampling sites marked by stakes. In Experiment 2 an area of 50 × 50 m was divided into 25 10 × 10 m sites. In both experiments petal samples were collected when the canola plants were at growth stage 4.2 (3). Samples were collected by walking around each site and reaching in at random to pick approximately the top 25 cm of inflorescences. Once enough inflorescences were collected to provide 100 petals per site, they were placed in clean plastic bags. The samples were processed in a nearby laboratory, usually within three hours of collection. In Experiment 1 samples were collected from sites 1-30 on July 8, 31-75 on July 9, and 76-100 on July 10. In Experiment 2 all samples were collected on July 19.

Individual petals were picked from the inflorescences and plated in 9-cm petri dishes containing sterile Difco potato dextrose agar with 20 ppm rose bengal and 30 ppm streptomycin sulfate. Only fully expanded petals were picked and normally no more than one petal was taken from each of four flowers per inflorescence. Four petals were plated per petri dish and a total of 100 petals were plated per sampling site. After incubating for 5-6 days at 25°C, petals were scored for the presence of *S. sclerotiorum*. The results were recorded as the number of infested petals per petri dish.

1986 — Three experiments were conducted, two near Melfort, and one near Meadow Lake in west-central Saskatchewan. The experiment at Meadow Lake was undertaken because of very low rainfall at Melfort during June and early July. Experimental sites were selected using similar criteria as in 1985. However, the area from which samples were collected was increased in order to be more representative of field scale variations in petal infestation. The number of petals tested per site was only 40 because the 1985 results showed that increasing the number to 100 from 40 had only a slight effect. The same procedure as in 1985 was followed for processing petal samples and recording results, except that a different isolation medium was used. This consisted of sterile Difco potato dextrose agar with 25 ppm anhydrous ampicillin and 25 ppm streptomycin sulfate. Laboratory studies with artificially infested petals indicated that this medium allowed more rapid identification of *S. sclerotiorum* in isolation dishes (12).

Experiment 3 at Meadow Lake consisted of 24 sampling sites, 12 spaced at 65 m intervals on each of the east and west sides of a 64 ha field of *B. napus* cv. Westar. The sites were marked by tall stakes and petal samples were collected on July 12 when the crop was at growth stage 4.1-4.2 (3). At Melfort Experiment 4 consisted of 25 sampling sites spaced

about 25 m apart, located from east to west along the north side of a 48 ha field of *B. napus* cv. Westar. Experiment 5 consisted of 10 sites in a triangular-shaped, 14 ha field of *B. campestris* cv. Tobin; six sites were situated along the south side and four along the east side, with all sites no less than 25 m apart. All sampling sites were marked with tall stakes. In Experiment 4 these stakes were placed along the edge of the field and petal samples were taken about 30 m into the field from each stake on July 13 when the crop was at growth stage 4.2 (3). However, in Experiment 5 samples were taken from the sampling sites on nine dates (July 17-24 and August 6) as the crop progressed from growth stage 4.1 to stage 4.4 (3). Enough inflorescences were collected within approximately 2 m of each stake on each date to provide 40 petals per site.

**Analysis of data.** Data were analyzed according to Snedecor and Cochran's (10) procedure for two-stage sampling. For the present experiments the estimated variance of the mean percentage of petal infestation (MPEI) has two components: (1) the component of variance for sites in a field ( $S_1^2$ ) and (2) the component of variance among dishes within sites ( $S_2^2$ ). The components are derived by performing a one-way ANOVA of MPEI per petri dish, with sites as the primary unit. In the ANOVA the mean square among sites (MSAS) represents  $S_1^2 + n_2 S_2^2$ , where  $n_2$  = number of petri dishes per site used in the experiment. The mean square among dishes (MSAD) represents  $S_2^2$ . Thus  $S_1^2 = (MSAS - MSAD)/n_2$ . In two-stage sampling components of variance can be used to calculate expected variances ( $S_y^2$ ) and standard errors ( $S_y$ ) for various sample sizes (10). In the present work the  $S_y = \sqrt{S_1^2/n_1 + S_2^2/n_1 n_2}$  where  $n_1$  = number of sample sites and  $n_2$  = the number of petri dishes per site.

**Disease incidence.** The same experimental areas that were used to study petal infestation also were used to investigate the influence of sample size on the accuracy of measurements of disease incidence (DI). In Experiments 1-5, DI was measured at each site in late August shortly before the crop was swathed by assessing the percentage of diseased plants in a sample of 200 plants. Using another procedure from Snedecor and Cochran (10), the sample size required to estimate DI with specified levels of precision was determined at  $P = 0.05$ . The specified levels were  $\pm 2.5\%$  DI,  $\pm 5.0\%$  DI, and  $\pm 10\%$  DI.

## Results

In Experiment 1 the mean percentage of petal infestation (MPEI) changed over the three days that samples were collected (Table 1). Thus the data



Table 1. Statistical data and analysis of variance of the percentage of petals infested with *Sclerotinia sclerotiorum* in five experiments

| Experiment            | MPEI | C.V. <sup>b</sup> | Analysis of variance of MPEI <sup>a</sup> per dish |      |                 | n <sub>2</sub> <sup>d</sup> | Estimated variance for sites (S <sub>1</sub> ) <sup>e</sup> |
|-----------------------|------|-------------------|----------------------------------------------------|------|-----------------|-----------------------------|-------------------------------------------------------------|
|                       |      |                   | Source                                             | df   | MS <sup>c</sup> |                             |                                                             |
| Experiment 1          |      |                   |                                                    |      |                 |                             |                                                             |
| Melfort 1985          |      |                   |                                                    |      |                 |                             |                                                             |
| (Sample sites 1-30)   | 85.9 | 14.0              | Sites                                              | 29   | 3600            | 25                          | 132.7                                                       |
|                       |      |                   | Dishes                                             | 709  | 284             |                             |                                                             |
| (Sample sites 31-75)  | 84.8 | 5.9               | Sites                                              | 44   | 620             | 25                          | 11.2                                                        |
|                       |      |                   | Dishes                                             | 1072 | 341             |                             |                                                             |
| (Sample sites 76-100) | 60.1 | 13.5              | Sites                                              | 23   | 1625            | 25                          | 38.0                                                        |
|                       |      |                   | Dishes                                             | 572  | 675             |                             |                                                             |
| Experiment 2          |      |                   |                                                    |      |                 |                             |                                                             |
| Melfort 1985          | 41.3 | 18.2              | Sites                                              | 24   | 1365            | 25                          | 32.9                                                        |
|                       |      |                   | Dishes                                             | 594  | 543             |                             |                                                             |
| Experiment 3          |      |                   |                                                    |      |                 |                             |                                                             |
| Meadow Lake 1986      | 7.1  | 57.6              | Sites                                              | 23   | 163             | 10                          | 0.4                                                         |
|                       |      |                   | Dishes                                             | 209  | 159             |                             |                                                             |
| Experiment 4          |      |                   |                                                    |      |                 |                             |                                                             |
| Melfort 1986          | 5.1  | 74.0              | Sites                                              | 24   | 139             | 10                          | 1.4                                                         |
|                       |      |                   | Dishes                                             | 223  | 125             |                             |                                                             |
| Experiment 5          |      |                   |                                                    |      |                 |                             |                                                             |
| Melfort 1986          |      |                   |                                                    |      |                 |                             |                                                             |
| (July 19)             | 7.3  | 59.6              | Sites                                              | 9    | 187             | 10                          | 0.2                                                         |
|                       |      |                   | Dishes                                             | 90   | 138             |                             |                                                             |
| (August 6)            | 35.4 | 30.0              | Sites                                              | 9    | 1099            | 10                          | 83.0                                                        |
|                       |      |                   | Dishes                                             | 89   | 269             |                             |                                                             |

<sup>a</sup>Mean % petal infestation for each experiment.<sup>b</sup>Coefficient of variation (based on mean % petal infestation per site).<sup>c</sup>Mean square among sites (MSAS) =  $S_2^2 + n_2 S_1^2$ ; Mean square among dishes within sites (MSAD) =  $S_2^2$ ;  $S_1^2$  = variance component for sites;  $S_2^2$  = variance component for dishes within sites.<sup>d</sup>n<sub>2</sub> = number of petri dishes per site used in experiment.<sup>e</sup> $S_1^2 = (MSAS - MSAD)/n_2$ .

were analyzed separately for each day. Data from Experiment 5 in 1986 were very similar for a number of the sampling dates. A gradual increase in MPEI occurred from July 17 to 24, but by August 6 MPEI had increased substantially, probably due to changing moisture conditions. In the present paper only data from July 19 and August 6 are presented. July 19 (7.3%) was chosen because MPEI was intermediate on this date relative to values on July 17 (1.75 %) and July 24 (11.75%).

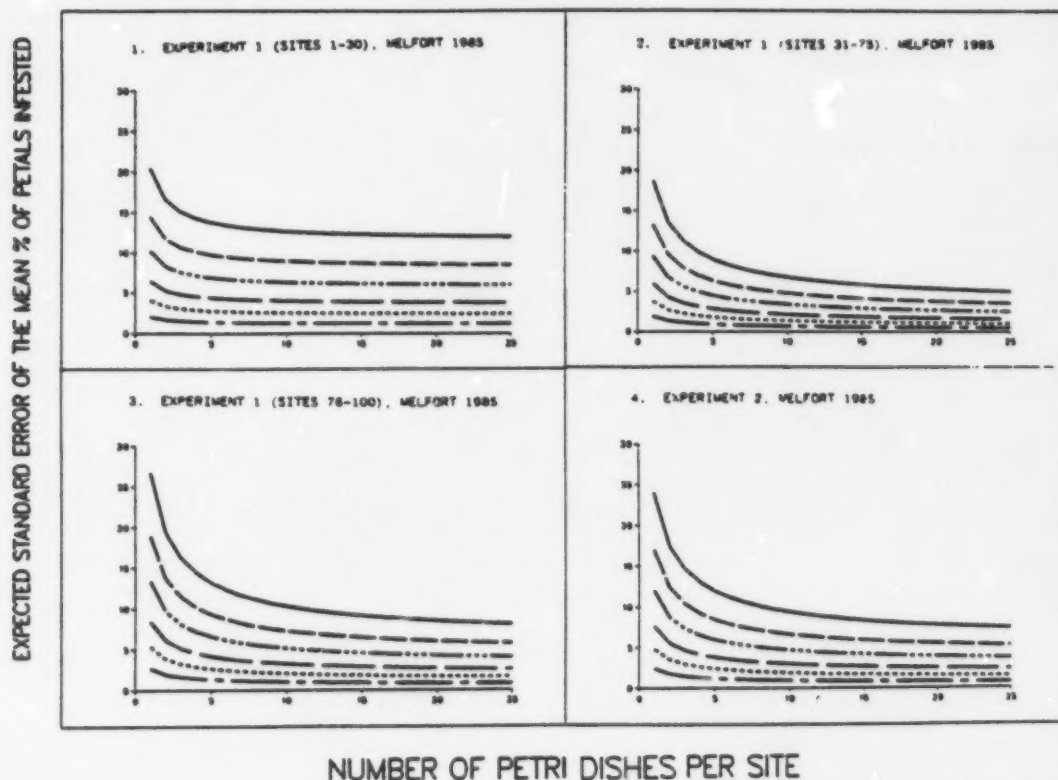
Results of ANOVA of MPEI per petri dish and  $S_1^2$  values for all experiments are shown in Table 1. Large differences among experiments in both  $S_1^2$  and  $S_2^2$  are evident. The  $S_1^2$  values for various numbers of sites and petri dishes (number of petals tested) within each site are presented graphically for all experiments in Figures 1-8. There was a general decrease in the  $S_1^2$  with increases in the number of sampling sites or petri dishes used within sites. However, there were differences among experiments in how quickly the  $S_1^2$  decreased with

increasing sample size. Overall the  $S_1^2$  for any given sample size was higher in 1985 than in 1986. In 1985 the  $S_1^2$  for any given sample size was slightly higher in Experiment 1 for sampling sites 1-30 than for sites 31-75 and 76-100 or in Experiment 2 (Figs. 1-4). In 1986 Experiments 3, 4, and 5 (July 19) produced similar  $S_1^2$  values for a given sample size, while values for Experiment 5 (August 6) were higher (Figs. 5-8).

The required sample sizes for measuring DI at the specified levels of precision varied greatly among experiments (Table 2). For Experiments 2 and 3 a larger sample size was required than in Experiments 1, 4, and 5. Of these, the lowest required sample size was in Experiment 5; those for Experiments 1 and 4 were slightly higher.

#### Discussion

The importance of sample size in estimating MPEI is illustrated by the derived  $S_1^2$  values, especially in Experiments 1, 2 and 5 (August 6). With only one or two sampling sites and few dishes



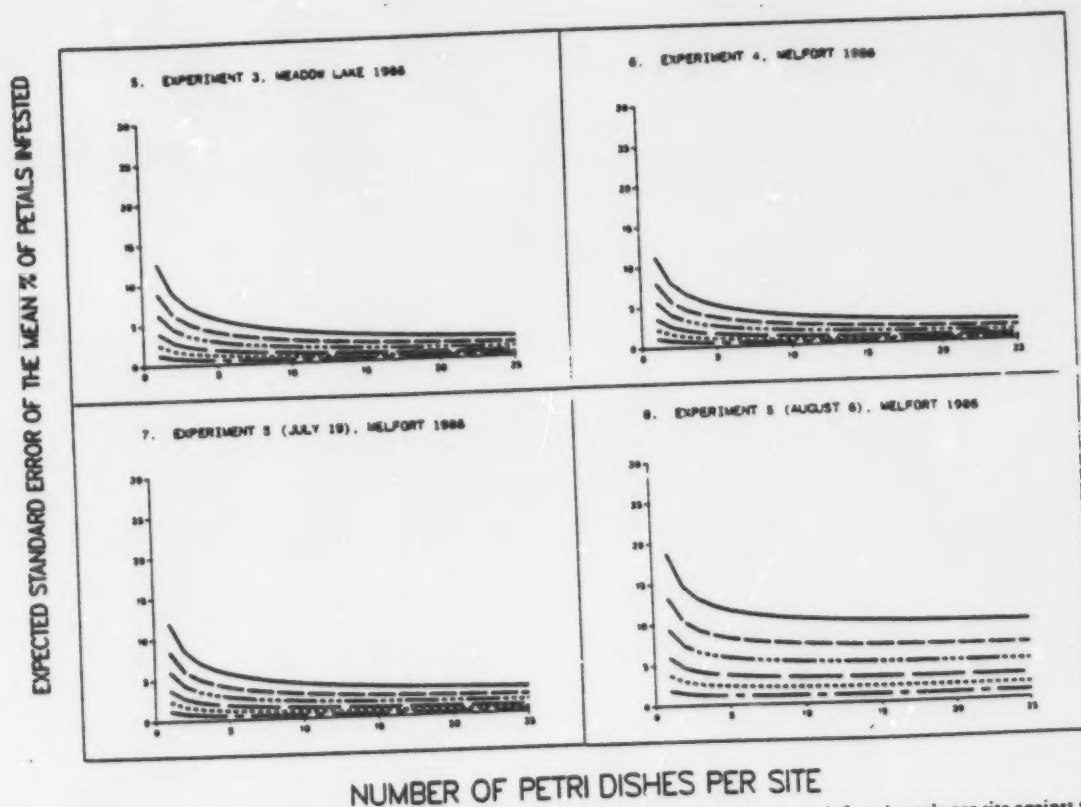
Figures 1-4. Plots of the expected standard error ( $S\bar{y}$ ) of the mean percentage of *S. sclerotiorum* infested petals per site against the number of petri dishes per site for 1 (—), 2 (---), 4 (— · —), 10 (— · — · —), 25 (— · — · — · —), and 100 (— · — · — · — · —) sampling sites for two experiments in 1985.  $S\bar{y}$  values calculated according to a procedure for two-stage sampling (10).

(petals) per site  $S\bar{y}$  was very large (Figs. 1-8). As the number of sites or the number of dishes per site was increased  $S\bar{y}$  decreased. However, the relationships differed among experiments. In Experiments 3, 4, and 5 (July 19) MPEI was very low (Table 1). Consequently the estimated variances among and within sampling sites were low and there were only small decreases in  $S\bar{y}$  with increased sample sizes. However, in Experiment 5 (August 6) MPEI and estimated variances were larger, and larger differences in  $S\bar{y}$  among sample sizes were apparent.

In the present experiments the MPEI values used in the ANOVA were limited to 0, 25, 50, 75, and 100% because the subunit was a single dish (4 petals). It might be argued that this limitation restricts the value of the analysis. This might be the case if additional variation not due to differences in MPEI occurred among the dishes. To test this

possibility the subunit size in two experiments with widely different MPEI values was increased from 1 dish (4 petals) to either 2 (8 petals) or 5 (20 petals). Variance components and  $S\bar{y}$  values were recalculated and compared. Only small differences resulted. For example, in Experiment 5 (August 10), sampling at 4 sites and testing 40 petals per site gave  $S\bar{y}$  values for  $10 \times 4$  petals,  $5 \times 8$  petals and  $2 \times 20$  petals of 5.2, 5.5, and 5.5, respectively. In Experiment 1 (July 8) corresponding  $S\bar{y}$  values were 6.3, 6.3, and 6.4, respectively.

The disease forecasting system being developed in our laboratory is dependent on farmers collecting petals themselves. Thus, the sample size must be small enough that farmers are willing to collect petals, but large enough to provide reliable estimates of MPEI. In a pilot project involving farmers in 1985 and 1986 (12) the sample size was arbitrarily set at four sites per field and 10 petri



Figures 5-8. Plots of the expected standard error ( $S_y$ ) of the mean percentage of *S. sclerotiorum* infested petals per site against the number of petri dishes per site for 1 (—), 2 (---), 4 (- · - · -), 10 (— · — · —), 25 (— · — · —), and 100 (·····) sampling sites for three experiments in 1986.  $S_y$  values calculated according to a procedure for two-stage sampling (10).

dishes (40 petals) per site. The present experiments indicate that this sample size could provide fairly accurate estimates of MPEI.

In 1985 the  $S_y$  values for four sampling sites and 10 petri dishes per site in Experiment 1 (July 8, 9, and 10) and Experiment 2 were 6.3%, 3.4%, 5.1%, and 4.7% respectively (Figs. 1-4). In Experiment 5 (August 6) the corresponding  $S_y$  was 5.2% (Figure 8). An  $S_y$  of about 5% would be acceptable in a practical disease forecasting system because it would have minor consequences relative to changes in MPEI with time (Table 1)(2). Experiments 3, 4, and 5 (July 19) gave less conclusive results because MPEI was very low. Despite high coefficients of variation (C.V.) calculated on the basis of MPEI per site (Table 1),  $S_y$  values were low. Thus, MPEI could still be estimated with an  $S_y$  of 5% without a large sample size (Figs. 5-7). Moreover, in practical forecasting accurate estimates are not important at

very low MPEI values because disease risk is minimal.

The sampling area used in some of the present experiments was small compared to the size of many commercial canola fields, which typically range from 20 to 80 ha. The distribution of sampling sites in the 1986 experiments suggests that  $S_y$  values calculated for both 1985 and 1986 experiments are representative of field-scale variations in MPEI. However, further work may be necessary to determine whether four sample sites and 10 dishes per site is adequate in large commercial fields in which MPEI exceeds 50%. If it were necessary to increase sample size, our results indicate that the most effective means of reducing  $S_y$  would be by increasing the number of sampling sites per field. The number of sites could be more than doubled without substantially increasing sampling effort and time. However, a substantial

Table 2. Statistical data on mean percentage of *Sclerotinia sclerotiorum* diseased plants (DI) per field and minimum sample size for estimating DI per field at  $P = 0.05$ 

| Experiment       | DI   | C.V. <sup>a</sup> | Specified level of precision |                |                 |
|------------------|------|-------------------|------------------------------|----------------|-----------------|
|                  |      |                   | $\pm 2.5\%$ DI               | $\pm 5.0\%$ DI | $\pm 10.0\%$ DI |
| Experiment 1     |      |                   |                              |                |                 |
| Melfort 1985     | 21.6 | 29.4              | 25.8 <sup>b</sup>            | 6.5            | 1.6             |
| Experiment 2     |      |                   |                              |                |                 |
| Melfort 1985     | 20.3 | 54.6              | 78.2                         | 19.6           | 4.9             |
| Experiment 3     |      |                   |                              |                |                 |
| Meadow Lake 1986 | 16.8 | 68.6              | 85.4                         | 21.3           | 5.3             |
| Experiment 4     |      |                   |                              |                |                 |
| Melfort 1986     | 5.1  | 125.0             | 26.2                         | 6.6            | 1.6             |
| Experiment 5     |      |                   |                              |                |                 |
| Melfort 1986     | 5.2  | 70.1              | 8.5                          | 2.1            | 0.5             |

<sup>a</sup>Coefficient of variation (based on mean DI per site).<sup>b</sup>Minimum sample size required for specified level of precision =  $4\sigma^2/L^2(10)$ ;  $\sigma$  = population standard deviation. L = specified level of precision (units on scale of measurement used).

increase in the time needed to process the petal samples would occur. This might be offset by decreasing the number of petals plated per sampling site. For example, in all experiments an increase of sampling sites from 4 to 10 and a corresponding decrease from 10 dishes to 4 (40 to 16 petals) would not have caused an increase in  $\bar{S}_y$  (Figs. 1-8).

In this study the C.V. values were 30% or less when MPEI exceeded 35% (Table 1). Such values may suggest relatively random distribution of infested petals in these fields. When measuring inoculum that is randomly distributed, the specific location of sampling sites in a field is not critical, provided enough sites are chosen. However, gradients of inoculum may occur when the source is aggregated (1) or is in an adjacent field (an area source, 13). Thus, parts of canola fields next to areas or fields where apothecia of *S. sclerotiorum* are abundant might have higher MPEI values than parts further away. The importance of gradients of inoculum of *S. sclerotiorum* in canola is not known and work in this area is needed (2). If an inoculum gradient was suspected, petal samples for disease forecasting could be collected accordingly.

The minimum sample size required to estimate disease incidence at specified levels of precision varied widely among the experiments. Experiments 2 and 3 indicated that about 20 sampling sites were required to achieve a precision level of  $\pm 5\%$  DI. However, Experiments 1, 4, and 5 indicated that fewer sampling sites were sufficient to achieve the same level of precision (Table 2). In our current pilot project (12) DI is determined at each of four sites in a field where petals have been collected. Judging by the above results, the accuracy of

estimation is quite low in fields similar to those in Experiments 2 and 3.

The difference among experiments in the sample sizes required to give specified levels of precision was related to crop density. In Experiment 1 the crop was relatively uniform and little lodging had taken place. However, in Experiments 2 and 3 which had similar mean DI, the crop was extremely dense and varied among sites in the amount of lodging that had occurred (Table 2). Disease incidence in the lodged areas was consistently higher than in the nonlodged areas, probably because of plant-to-plant spread of the fungus. Thus, variation among sampling sites was much higher in Experiments 2 and 3 than in Experiment 1, suggesting an aggregated rather than random distribution (Table 2). The variation was reflected by larger sample sizes required for specified levels of precision and high C.V. values.

In Experiments 4 and 5 high C.V. values also occurred (Table 2). However, this was not reflected in high minimum sample sizes needed for specified levels of precision. This was because DI was much lower than in Experiments 1-3 (Table 2). The high C.V. values reflected systematic trends in canopy density and DI. For sites 1-13 in Experiment 4 the stand was light and the mean DI was 1.8%. At sites 14-25 the stand was denser and mean DI was 8.8%. For sites 1-5 in Experiment 5 mean DI was 2.3%. At sites 6-10 the stand was denser and mean DI was 8.1%. The results of Experiments 1, 4, and 5 suggest that when sclerotinia stem rot is assessed in canola fields, such as in our current pilot project, a minimum of five or six sampling sites should be used to achieve a precision level of  $\pm 5\%$  DI. If stands are highly variable as in Experiments 2 and



3, it will be necessary to increase the sample size considerably or make specific assessments in lodged and non-lodged areas of the field, to achieve the same precision level.

Although formal analysis of distribution patterns using variance-to-mean ratios is inappropriate with the present percentage data (6), it is noteworthy that C.V. values were lower for MPEI than for DI in all experiments. This may indicate that there was a more random distribution of ascospore-infested petals than of diseased plants. Boland (1) showed that in white bean and soybean crops in Ontario the distribution of both apothecia of *S. sclerotiorum* and white mold disease were aggregated. It is to be expected that ascospores will be more randomly distributed in a crop than the apothecia from which they are discharged because of spore dispersal by air currents. When inoculum is randomly distributed, sampling to assess disease risk will be inherently easier than when it is aggregated. However, it must be recognized that agronomic factors such as lodging and stand density can lead to nonrandom distribution of disease, even when inoculum is randomly distributed.

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Appendix D. Summary of MPM professional paper (thesis) by D.A. Kaminski.  
(1987).

## Appendix D

### ASSESSING THE SUITABILITY OF A SCLEROTINIA RISK PREDICTION KIT FOR HOME USE BY CANOLA GROWERS

By David A. Kaminski

Summary of professional paper submitted in partial fulfillment of the requirements for the degree of Master of Pest Management at Simon Fraser University.

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## INTRODUCTION

A major disease of canola (rapeseed) in western Canada is stem rot caused by Sclerotinia sclerotiorum (Lib.) deBary. All Canadian cultivars of both species of canola (Brassica napus L. and B. campestris L.) are highly susceptible. However, the epidemiology and response to environmental factors of the disease are such that percentage disease incidence (DI) varies greatly from year to year, region to region and even from field to field within regions and years (7,11,12). Thus, disease forecasting is important for the rational use of fungicides to control stem rot. Benomyl and iprodione are registered in Canada for this purpose at 0.5 kg a.i./ha, but are often used at 0.6 kg a.i./ha (= 0.5 lb/acre). Single applications at early to full bloom may reduce DI dramatically (4,15,16,19,20) but the cost of treatment is about \$50 CAN /ha. Both registered fungicides have been vigorously promoted by their respective manufacturers in the past two years in western Canada.

Useful disease management programs necessitate an understanding of the relationship of yield loss to DI or disease severity, especially if fungicide application may be recommended. However, rather limited information is available in the literature on the effects of sclerotinia stem rot on yield of canola in Canada (4,13,19,20). Morrall et al. (13) estimated that losses in four fields in Saskatchewan in 1975 were in the range of 10-15%, even though DI varied from 20 to 62%. Much of what has been published on yield losses consists of non-replicated fungicide tests at a field scale; typically, yields and disease have been compared between



## ABSTRACT

The relationship of yield to disease incidence in sclerotinia stem rot of canola was studied by linear regression analysis of data from fungicide trials in Saskatchewan in 1980, 1983 and 1984. By rearrangement of the regression equations, percentage yield loss in each trial was expressed as  $100b/a \times \text{Disease incidence}$ . For those regressions which were significant and where the  $R^2$  values exceeded 0.2, all values of  $100b/a$  were between 0.34 and 0.76 with a mean of 0.50. The value of 0.50 is similar to average values for percentage yield loss per unit reduction in percentage disease incidence demonstrated in studies in Alberta, Germany and the U.K. Applications of benomyl, iprodione or vinclozolin to canola at 0.25-0.30 kg a.i./ha at early bloom usually gave a substantial level of control of sclerotinia stem rot. When disease pressure was low, these treatments were often as effective as applications at the recommended dose of 0.5 kg a.i./ha. Splitting the application of the recommended dose between early and full bloom gave excellent control. The results are discussed in relation to disease forecasting and practical management of the disease.

## INTRODUCTION

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individual sprayed and non-sprayed strips or parts of fields, each up to several ha in extent (15,16,19). Such data are often highly variable, partly because other factors strongly influence yield. For example, figures in the Canola Growers' Manual (19) from 17 tests in 1981-82 in Alberta show that the differential in DI between sprayed and non-sprayed areas ranged from 15 to 66% infected plants. The yield increases ranged from -156 to 1333 kg/ha. Of more interest, however, is the fact that the percentage yield increases due to spraying, when calculated per unit reduction in %DI, varied from -0.56 to +0.91 (mean +0.43). With such a wide range, there is a risk that vested interests may use the data selectively to exaggerate effects of disease on yield, rather than concentrate on the mean relationship.

A recent decline in the market value of canola to about half its worth in early 1984 has changed the economics of chemical control of stem rot. Whereas at one time a yield increase of only 140 kg/ha was sufficient to pay for the cost of fungicide application, nearly 300 kg/ha is now necessary. Yields commonly range from 1400 to 2300 kg/ha in Saskatchewan (17,19). Thus, the "breakeven yield increase" for fungicide application at recommended rates is now between 13 and 21%. In such an economic climate, growers need both sound economic advice about yield loss relationships and less expensive options in chemical control.

The purpose of the present study was (a) to re-examine data from western Canada, most of them previously published, and determine the general relationship between percentage yield loss and disease incidence in sclerotinia stem rot, and (b) to investigate the biological consequences of using three fungicides at reduced doses of

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active ingredient and attempt to develop alternative strategies of chemical control. Reports of parts of this work have been previously published (4,14,15,16,17,21).

#### MATERIALS AND METHODS

##### Yield loss relationships

Previously published and unpublished data were used to calculate linear regressions of canola yield on DI. All yields were adjusted to tonnes/ha. The data were derived from small plot and field-scale fungicide trials in which a range of DI values had been obtained.

A small plot experiment conducted in 1980 (Reference 4, Table 2, Leask 1) was designated Test 1. Although disease data had originally been presented in the form of disease indices (4), DI values were also available. Individual plot values were used in the regression analysis. Tests 2-4 were small plot experiments conducted in 1983 (Reference 21, Fields 1-3 respectively). Again, the published data were in the form of disease indices (21), but DI values from individual plots were used in the regression analyses. Tests 5-7 were large scale experiments conducted in 1983 to compare aerial and ground-level fungicide application (Reference 15, Fields 1-3 respectively). Values used in the regression analyses were means of multiple samples for DI, but usually single treatment values for yield (15).

Tests 8-13 were conducted in 1984 and consisted of large scale experiments involving ground-level application of fungicides. The DI data were derived from multiple samples in each treatment strip (16).



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Although not previously reported, yields were determined in these tests by weighing the product of one or two swaths (windrows) that ran the entire length of each treatment strip. In Tests 10-13 in which several treatments gave similar DI values, yields in one or more treatment strips were not determined in order to minimize inconvenience to the co-operating grower at harvest. In Test 9, one treatment strip was omitted after yield determination because it was an obvious outlier that could be accounted for by soil fertility.

#### Reduced fungicide doses

Part of the data in Table 2 of Reference 4 were used to investigate the quantitative relationship between control of sclerotinia stem rot and dose of benomyl. The values for the four doses of benomyl (1.0, 0.75, 0.5 and 0.25 kg a.i./ha) and the benomyl plus oil treatments (0.25 kg a.i. + 2.7 L/ha) were included. Since a plot of disease index against dose of benomyl as well as theoretical considerations suggested a negative logarithmic dose response, the disease indices were  $\log_e$  transformed. Linear regressions of  $\log_e$  disease index on dose of benomyl were then calculated for each site.

Part of the data presented in Reference 16 were also used to evaluate the efficacy of benomyl, iprodione and vinclozolin when used at about half normal doses, or when the normal dose was split between two applications. DI data from Tests 8,9,10,12 and 13(above) were used. Comparisons were made between DI in treatments involving application at 0.3 kg a.i./ha or 0.3 + 0.3 kg a.i./ha and treatments involving application at 0.6 kg a.i./ha at growth stage 4.2 or 4.3 (8). Separate comparisons for each fungicide were made as follows:

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|                                                                               |         |                            |   |                                                                                  |
|-------------------------------------------------------------------------------|---------|----------------------------|---|----------------------------------------------------------------------------------|
| % Efficacy of a fungicide treatment relative to treatment at recommended dose | = 100 X | Mean DI of checks in field | - | Mean DI of the treatment                                                         |
|                                                                               |         | Mean DI of checks in field | - | Mean DI for same fungicide used at 0.6 kg a.i./ha at growth stage 4.2 and/or 4.3 |

A small-plot experiment was established in early July, 1986 at Meadow Lake, Saskatchewan (300 km N.W. of Saskatoon) in a commercial field of rapeseed cv. Triton. Apothecia were present in the part of the field where the plots were located. The treatments consisted of applications on either or both of two spray dates, using three fungicides at half the recommended doses (0.25 kg a.i./ha in all cases). All possible combinations of any two of the fungicides were tested in the dual applications. Plots were 6 X 2 m and replicated four times in a randomized complete block. The dates of application were July 8, when the crop was at growth stage 4.2 (8) and July 18, when it was at growth stage 4.3. On both dates plots were either not sprayed, or sprayed with benomyl, iprodione or vinclozolin, giving a total of 16 treatment combinations. Fungicides were applied with a hand-held Model G-3, R and D Sprayer\* operating at 276 kpa with LF3 nozzles. The volume of fluid applied was equivalent to 333 l/ha. DI was assessed on August 12, shortly before the crop was swathed, by counting the number of plants with one or more stem lesions from a sample of 200 plants taken from the middle of each plot. The results were analysed by ANOVA and orthogonal contrasts of specific treatments.

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\*R and D Sprayers Inc, Opelousas, La, 70570, U.S.A.

## RESULTS

## Yield loss

The  $R^2$  values from the regression analyses were sometimes low, particularly when there was a small number of degrees of freedom or when the data were clustered on one or both axes (Table 1). For example, most of the regressions of 1984 data were not significant. However, scattergrams of the data used in the regression analyses provided no evidence for other than a simple linear relationship between yield and DI.

In a series of tests in which DI-yield relationships are investigated, the yield potential varies due to factors unrelated to the disease. In the present work this is reflected in a range of "a" values for the regression equations from 1.50 to 2.59 t/ha (Table 1). For those regressions which were significant, the values of "a" are realistic predictors of yield in the absence of disease because they are determined without extensive extrapolation beyond the data points. In most of the tests the lowest DI values were close to 0 (Table 1). Thus, the regression equations ( $y = a - bx$ ) express the relationship: Actual yield = Potential yield - b (DI) for each test. In order to generalize the relationship between yield loss and disease without regard to variation in yield,  $y = a - bx$  can be modified as follows:

Rearrangement gives:  $a - y = bx$

Multiplying both sides by  $100/a$  gives:  $100(a - y)/a = 100bx/a$

i.e.  $\frac{100(\text{Predicted yield} - \text{Actual yield})}{\text{Predicted yield}} = (100b/a)DI$

Hence % Yield loss =  $100b/a \times \text{Disease incidence}$

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The values of  $100b/a$  for each regression are shown in Table 1. It is noteworthy that for those regressions which are significant at  $p = 0.05$  and for which the  $R^2$  value is  $>0.20$  (i.e. Tests 1-3, 5-6 and 13) all values of  $100 b/a$  fall between 0.34 and 0.76 with a mean of 0.50.

#### Fungicide doses

Disease pressure in the 1980 experimental plots was high in two out of three cases (4). Disease indices of 60% represented DI values of about 80%. High  $R^2$  values were obtained from all regressions of  $\log_e$  disease index on dose of benomyl:

Stoney Plain:  $\log_e$  Disease index =  $3.18 - 1.29 [\text{benomyl}]$ .  $R^2 = 0.66$   
 Leask 1:  $\log_e$  Disease index =  $3.95 - 1.57 [\text{benomyl}]$ .  $R^2 = 0.99$   
 Leask 2:  $\log_e$  Disease index =  $3.96 - 1.60 [\text{benomyl}]$ .  $R^2 = 0.94$

From these three equations it can be calculated that benomyl at 0.5 kg a.i./ha gave 48, 54 and 55 % control, respectively. Similarly, benomyl at 0.25 kg a.i./ha gave 29, 33 and 33% control, respectively. Thus, in each case half doses gave about 60% of the control obtained with full doses.

In the 1984 experiments with three fungicides, single applications at 0.3 kg a.i./ha produced variable results when control was calculated as a percentage of that achieved with 0.6 kg a.i./ha (Table 2). However, in half of the cases percentage efficacy was 100% or more of that obtained with the higher dose. In Test 13, where disease pressure was low (16), all three fungicides give similarly



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good results in this respect. Split applications of 0.3 + 0.3 kg a.i./ha were highly effective in all but one case (Table 2).

In the small plot experiment in 1986 DI in the non-treated plots was about 30%. Almost all treatments significantly reduced the level of disease (Table 3). An orthogonal contrast between the two dates of application was significant at  $p = 0.0001$ . Single applications on July 18 were clearly less effective than those on July 8 and in the case of benomyl gave no significant reduction in DI compared with the check (Table 3). When iprodione or benomyl were applied on July 8, a second application of any of the three fungicides had no additional effect on DI; however, when vinclozolin was applied on July 8, all second fungicide applications further reduced DI significantly.

#### DISCUSSION

Variations in the values of  $100b/a$  derived from the regression equations in Table 1 may be related to environmental factors and time of host infection. In a disease such as sclerotinia stem rot it is to be expected that early infections will result in greater yield reduction than late infections. Late infections are more likely to occur high up in the crop canopy and cause shrivelling of the pods in only a part of the branching inflorescence. Thus, time of infection will affect the value of  $b$  in the regression. The generally poor correlation between yield and DI in 1984 and low values of  $100b/a$  may have been partly due to abnormally hot dry weather in late July and early August. The plants ripened rapidly and seed may have failed to set properly in some healthy plants. This would have tended to reduce the yield differential between healthy and infected plants.

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The more reliable values of 100 b/a from Table 1 ranged from 0.36 to 0.76 with a mean of 0.50. It is also noteworthy that the mean value of 100b/a for all 13 regressions is 0.45. Both of these figures are similar to the value of 0.43 derived by averaging data in the Canola Growers' Manual (19) for percentage yield loss per unit reduction in % DI. The latter statistic is essentially the same as 100b/a.

The results of the present analyses of Canadian data are similar to those of studies illustrating yield loss in winter rape in Europe. In Germany Kruger and Stoltenberg (9) assembled data collected over a period of several years from farm and plot trials with vinclozolin and showed a wide range of percentage yield increases from spraying. In many of the trials fungicide application did not prove to be economically worthwhile, especially when DI was low. However, in assessing all the results combined, Kruger and Stoltenberg showed a significant, but low positive correlation ( $r = 0.48$ ) between the relative increase in yield from spraying and DI. Figure 2 of their paper (9) suggests that the mean quantitative relationship between the two variables is: % Yield decrease =  $0.5 \times \% \text{ DI}$ . On the other hand, data from a single fungicide trial in the U.K. reported by Davies (2) suggest a slightly greater mean effect of DI on yield loss. Regression analysis of the values in Table 6.3 of Davies' article (2) results in the following equation:

$$\text{Yield} = 3.77 - 0.0204 \text{ DI. } R^2 = 0.73. \quad p < 0.005.$$

By the steps used above, the value of 100b/a for this trial is 0.541, which is towards the higher end of the range shown in Table 1.

In the light of figures presented in this paper, it appears that

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a reasonable rule of thumb for Canadian growers to follow in estimating percentage yield loss from DI would be to multiply by 0.5. Thus, on average a yield loss of 25% might be expected in a field with 50% DI. References by chemical manufacturers and dealers to losses of 50% or more should, therefore, be recognized as extreme cases; they normally would occur only when DI was 100%. In Saskatchewan, DI values greater than 30% are relatively uncommon (11,12,T.K. Turkington, unpublished data).

Results from tests in 1980, 1984 and 1986 (4,16) indicate that a substantial measure of control of sclerotinia stem rot can be achieved with benomyl, iprodione or vinclozolin at half the recommended dose. Vinclozolin, though not yet registered in Canada, is widely used in Europe (9,10) on winter rape. When disease pressure was relatively low, as in Tests 9 and 13 in 1984 and in the 1986 test, half doses at growth stage 4.2 usually provided a very high level of control; DI was reduced to less than 10%. This suggests an option in chemical control that would be less expensive than application at the regular dose. It would be particularly useful to growers if integrated with more effective methods for disease forecasting, so that fields at only moderate disease risk could be identified (7). In addition, there is clearly a need to investigate how physical aspects of application may increase the efficacy of control of sclerotinia stem rot with low doses of fungicides. These physical factors include boom height, spray pressure and nozzle type which all interact to affect spray droplet size and coverage of the target crop (18).

Split applications at half the recommended dose also offer an option in chemical control which is evidently very effective even

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under high disease pressure (Tables 2,3). Specifically, dividing the application of a fungicide between early and full bloom provides the grower with a longer period in which to evaluate weather conditions and other risk factors before investing in the full price of chemical control. Split applications could also be integrated with new methods of assessing disease risk at early bloom (7). Since the fungicides used to control sclerotinia stem rot are relatively site-specific, there is a risk of fungicide tolerance developing in the pathogen population (3,6). Indeed, cross resistance to dicarboximides, such as iprodione and vinclozolin, has been reported (5). Thus, there would be a clear advantage to using different classes of fungicides for each treatment when split applications were used. This type of approach is now being recommended under certain circumstances in France (10). In a similar connection, a fungicide now being marketed in France for use on rapeseed against S. sclerotiorum consists of a mixture of a benzimidazole and a dicarboximide (1).

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Table 1. Data for linear regression of rapeseed yield on disease incidence of sclerotinia stem rot.

| Test No. | Reference | Year | Cultivar | Range of DI* values | Range of Yield Values (t/ha) | Regression Equation $y = a - bx$ | R <sup>2</sup> Value | df | Significance level of regression | $\frac{100b}{a}$ |
|----------|-----------|------|----------|---------------------|------------------------------|----------------------------------|----------------------|----|----------------------------------|------------------|
| 1        | 4         | 1980 | Altex    | 11 - 93             | 0.82 - 2.29                  | $y = 2.33 - 0.0118x$             | 0.61                 | 74 | $p < 0.001$                      | 0.51             |
| 2        | 21        | 1983 | Westar   | 0 - 60              | 1.04 - 2.40                  | $y = 1.67 - 0.0067x$             | 0.21                 | 66 | $p < 0.001$                      | 0.40             |
| 3        | 21        | 1983 | Westar   | 5 - 84              | 0.98 - 2.59                  | $y = 2.10 - 0.0100x$             | 0.45                 | 66 | $p < 0.001$                      | 0.48             |
| 4        | 21        | 1983 | Andor    | 0 - 27              | 0.99 - 2.19                  | $y = 1.61 - 0.0139x$             | 0.08                 | 56 | $p < 0.020$                      | 0.86             |
| 5        | 15        | 1983 | Westar   | 6 - 65              | 1.68 - 2.33                  | $y = 2.36 - 0.0121x$             | 0.85                 | 9  | $p < 0.001$                      | 0.51             |
| 6        | 15        | 1983 | Tobin    | 6 - 63              | 1.26 - 1.61                  | $y = 1.57 - 0.0053x$             | 0.80                 | 5  | $p < 0.010$                      | 0.34             |
| 7        | 15        | 1983 | Regent   | 0 - 10              | 1.63 - 1.76                  | $y = 1.76 - 0.0132x$             | 0.72                 | 2  | $p < 0.200$                      | 0.75             |
| 8        | 16        | 1984 | Westar   | 1 - 59              | 1.50 - 1.75                  | $y = 1.63 - 0.0007x$             | 0.05                 | 10 | $p > 0.500$                      | 0.04             |
| 9        | 16        | 1984 | Westar   | 3 - 27              | 1.70 - 1.98                  | $y = 1.90 - 0.0009x$             | <0.01                | 6  | $p < 0.900$                      | 0.05             |
| 10       | 16        | 1984 | Westar   | 3 - 54              | 1.62 - 2.08                  | $y = 2.03 - 0.0049x$             | 0.23                 | 9  | $p < 0.200$                      | 0.24             |
| 11       | 16        | 1984 | Westar   | 2 - 16              | 1.37 - 1.53                  | $y = 1.50 - 0.0072x$             | 0.25                 | 2  | $p > 0.500$                      | 0.48             |
| 12       | 16        | 1984 | Tobin    | 0 - 22              | 1.41 - 1.75                  | $y = 1.67 - 0.0080x$             | 0.33                 | 9  | $p < 0.100$                      | 0.48             |
| 13       | 16        | 1984 | Westar   | 0 - 20              | 1.90 - 2.74                  | $y = 2.59 - 0.0198x$             | 0.42                 | 8  | $p < 0.050$                      | 0.76             |

\*DI = % infected plants



## INTRODUCTION

There are two fungicides registered against sclerotinia stem rot in Canada, Benlate and Rovral Flo. The cost of these chemicals makes it advantageous to growers to have a good indication of the risk of infection before deciding whether or not to spray. The timing of this decision is also important. Control measures are usually most effective when implemented early in the bloom period which lasts 2-3 weeks.

Traditionally, the risk of sclerotinia infection was assessed by searching the soil surface for apothecia when conditions favoured germination of sclerotia. Such searching is difficult and often unreliable for a number of reasons. Apothecia are small (about 6 to 10 mm dia.), inconspicuous among plant debris, and like sclerotia, nonuniformly distributed. Consequently, apothecia may be present in a canola crop but escape detection. On the other hand, they may truly be absent but, nevertheless, significant disease develops. The reason is that spores are forcibly ejected from apothecia; they escape the still air within the closed canopy and are carried a considerable distance. Thus inoculum may actually originate in adjacent fields.

The distribution of spores, above and within a canola field, is much more uniform than that of sclerotia. A method that can quantify spore inoculum levels in a crop would be a more relevant indicator of disease risk than searching for apothecia. Such a method has been realized with the advent of petal testing. Petal testing at early bloom in canola crops has been studied in a pilot project at Melfort since 1985. The test involves plating petals on a selective medium to detect the presence of sclerotinia on or within the tissues. Growers have made use of this method by collecting flowering shoots and bringing them to a centrally located laboratory. There the testing is done by trained technicians. Results, given in terms of percent petal infestation and a subsequent disease risk (low, moderate, or high), can be related to growers over the phone after 3 1/2 days.

The kind of plant material tested must be processed within hours of collection. Thus, the distance a grower might travel to have petal samples tested has limits. The main drawback of conducting the test at a central laboratory was that it restricted the service to a small geographic area. This led to the search for a means to make petal testing and prediction of the risk of sclerotinia infection more widely available. To that end, the materials employed in testing and instructions for using these materials were assembled in a prototype "kit". The results obtained by canola growers using the kit were compared to those obtained by trained technicians using standard laboratory procedures. Both sets of individuals collected flowering shoots from the same sites at about the same time.

The objective of this study was to assess the kit's suitability and identify factors that might contribute to its success or failure. Cooperators were asked to participate in evaluating the kit through an anonymous questionnaire and through a subjective personal interview.

Finally, opinions were sought on possible improvements to the kit and on its feasibility for development as a commercial product.

## MATERIALS AND METHODS

### Preliminary Considerations

A target of 30 cooperators was chosen as one which would constitute a manageable sample size. This group could not be considered a random sampling. Selection was based on two criteria, namely past participation in the "Sclerotinia Project" and apparent interest to support such cooperative ventures. The former selection criterion defined the geographic area in which the candidates would be located. Forty-five canola growers were sent letters asking for their participation. Of the 45 growers approached, 32 consented. Four of those who agreed to participate were later unable to do so and one person was added resulting in a final tally of 29 cooperators.

### Materials

Each cooperator was provided with materials and instructions in the form of a kit in advance of the time prescribed for petal testing. In addition to the kit, 21 of the growers received a 7 minute, VHS-format videocassette tape. This tape duplicated the information supplied by the written instructions as an audiovisual demonstration of techniques. Eight of the cooperators either did not have a video cassette recorder or chose not to use the tape.

### Methods

When a grower decided his crop was at the correct stage for sampling, he selected about 10 flowering shoots (one sample) from each of four sites. After returning from the field, he plucked four or five petals from each shoot. These were placed in a separate dish until it contained the 40 petals needed for each site. He then placed the petals, four to a plate, on the 10 culture plates for one site, placed the stack of plates inside a storage bag, closed it with a twist tie, and labelled it appropriately. Forceps were sterilized between samples by dipping in disinfectant and waving them until they were airdried. Reading the results was not expected of growers in this study. After 3 1/2 days in storage, the plates were examined by the project coordinator.

The procedure for testing canola petals was similar for both growers and lab technicians with a number of minor exceptions. Lab technicians disinfected forceps periodically, even while plucking petals from the sample study, by dipping them in ethyl alcohol and flaming them over an alcohol burner. Growers were asked to disinfect the forceps without flaming them and only between samples from different sites. In the lab, plating was done under a laminar-flow transfer hood. Since such equipment is unavailable on a farm, the instruction given for on-farm plating was that the workspace be "clean".

Sampling and plating were carried out by growers and technicians within a few hours of each other. Sampling was done independently but

at previously marked sites so that the grovers and technicians collected from the same general plant population.

In the lab, culture plates were stored unbagged in incubators at 25°C. On farms, plates were placed in plastic bags and stored in a variety of locations, the only stipulation being that they not be exposed to direct sunlight.

#### Evaluation Procedures

Each cooperator was given the option of testing just one or several fields. Seven did two fields and one did four. Thus, a total of 39 fields was tested between June 26 and July 15, 1987. Results were tabulated by the project coordinator, usually with the grower in attendance. The time required by a trained technician to read a set of culture plates was a maximum of 10-15 minutes. Whenever possible, grovers were shown sclerotinia in culture, the common contaminants and problems, if any, arising from their technique.

#### Data Collection

Three items of information were collected from the 10 culture plates for each sampling site: number of petals obscured by growth of contaminants, the number dislodged from the medium, and the percentage of the remainder infested with sclerotinia. Grovers' and technicians' results were noted on the same data sheet. The term "technicians" refers to members of the laboratory staff: summer students, graduate students, technicians, and a professor, all of whom had considerable training and experience in plant pathological techniques. For the sake of comparison, technicians were treated as a theoretically homogenous group of individuals.

#### Assessment by Cooperators

Grover's opinions concerning the suitability of the kit for sclerotinia risk prediction were polled in two ways. First, they filled out an anonymous questionnaire. The questions were posed so as to require simple "yes/no" answers. The second means of assessment gave cooperators the opportunity for personal input and expression. Questions were put forward in the context of an in-person interview and the coordinator made brief notes on the grovers' responses. Among the four sections covered was one asking grovers' ages and educational backgrounds. This was intended to establish a "grover profile", to gauge how representative a sample of potential users had been obtained through the non-random selection process employed. The remaining sections dealt with the use of the kit, the theoretical basis of petal testing, and future directions for the system.

### **RESULTS**

#### Petal Infestation

Percent petal infestation (XPI) determined by grovers and by technicians, was compared using a paired-sample statistical analysis. It showed that there was no significant difference between grovers' and technicians' estimates of XPI (Table 1).

TABLE 1. Results of petal testing for *Sclerotinia* infection by growers and technicians.

| Sample no. | % petal infestation |            | differences | Rhizopora contamination |            | # petals out of 160 obscured by: |            |
|------------|---------------------|------------|-------------|-------------------------|------------|----------------------------------|------------|
|            |                     |            |             |                         |            | dislodging                       |            |
|            | GROWER              | TECHNICIAN |             | GROWER                  | TECHNICIAN | GROWER                           | TECHNICIAN |
| 1          | 1                   | 1          | 0           | 36                      | 4          | 0                                | 0          |
| 2          | 1                   | 0          | -1          | 11                      | 4          | 0                                | 0          |
| 3          | 1                   | 1          | 0           | 8                       | 4          | 7                                | 0          |
| 4 (3)      | 1                   | 1          | 0           | 4                       | 22         | 1                                | 0          |
| 5          | 0                   | 3          | 3           | 12                      | 8          | 0                                | 0          |
| 6          | 4                   | 0          | -4          | 0                       | 4          | 0                                | 0          |
| 7 (6)      | 0                   | 3          | 3           | 4                       | 4          | 0                                | 0          |
| 8 (6)      | 2                   | 1          | -1          | 4                       | 4          | 0                                | 0          |
| 9 (6)      | 0                   | 1          | 1           | 4                       | 4          | 0                                | 0          |
| 10         | 0                   | 0          | 0           | 12                      | 0          | 0                                | 0          |
| 11         | 0                   | 0          | 0           | 4                       | 24         | 37                               | 0          |
| 12         | 2                   | 1          | -1          | 0                       | 0          | 0                                | 0          |
| 13         | 1                   | 2          | 1           | 0                       | 3          | 0                                | 0          |
| 14 (13)    | 2                   | 3          | 1           | 4                       | 0          | 0                                | 0          |
| 15         | 3                   | 2          | -1          | 9                       | 0          | 0                                | 0          |
| 16         | 1                   | 1          | 0           | 0                       | 0          | 0                                | 0          |
| 17         | 4                   | 3          | -1          | 4                       | 11         | 0                                | 0          |
| 18         | 0                   | 1          | 1           | 19                      | 26         | 0                                | 0          |
| 19 (15)    | 3                   | 3          | 0           | 1                       | 0          | 0                                | 0          |
| 20         | 2                   | 0          | -2          | 0                       | 0          | 0                                | 0          |
| 21         | 0                   | 0          | 0           | 8                       | 1          | 0                                | 0          |
| 22 (2)     | 3                   | 1          | -2          | 2                       | 0          | 0                                | 0          |
| 23         | 0                   | 3          | 3           | 11                      | 4          | 0                                | 0          |
| 24 (23)    | 1                   | 0          | -1          | 4                       | 4          | 0                                | 0          |
| 25         | 0                   | 4          | 4           | 11                      | 8          | 0                                | 0          |
| 26         | 3                   | 3          | 0           | 34                      | 1          | 0                                | 0          |
| 27         | 2                   | 31         | 29          | 14                      | 16         | 0                                | 0          |
| 28         | 4                   | 6          | 2           | 2                       | 0          | 13                               | 0          |
| 29         | 9                   | 6          | 3           | 0                       | 0          | 0                                | 0          |
| 30         | 6                   | 8          | 2           | 1                       | 0          | 0                                | 0          |
| 31         | 4                   | 12         | 8           | 4                       | 0          | 1                                | 0          |
| 32 (16)    | 5                   | 4          | -1          | 4                       | 0          | 0                                | 0          |
| 33         | 3                   | 14         | 11          | 0                       | 0          | 0                                | 0          |
| 34         | 1                   | 1          | 0           | 4                       | 15         | 20                               | 0          |
| 35         | 40                  | 32         | -8          | 1                       | 11         | 0                                | 0          |
| 36         | 9                   | 17         | 8           | 6                       | 2          | 0                                | 0          |
| 37 (28)    | 7                   | 4          | -3          | 6                       | 4          | 0                                | 0          |
| 38         | 3                   | 3          | 0           | 3                       | 6          | 0                                | 0          |
| 39         | 38                  | 42         | 4           | 4                       | 19         | 13                               | 0          |



The range of XPI (means of pairs) was from 0% to 40%. The maximum observed XPI is borderline between low and moderate disease risk categories. This was the result of an abnormally dry period in the study area throughout early crop development. Generally, only later seeded crops showed > 5XPI and the distribution of all XPI data was strongly skewed toward the lower limit.

#### Petals obscured by contamination

Rhizopus bread mould was the only contaminant encountered that prevented detection of sclerotinia. It was probably introduced to the medium via airborne spores during plating and grew so quickly that it obscured all other colonies. No association was seen between the number of petals obscured by contamination and XPI. The other common contaminants slowed the growth of sclerotinia but did not prevent its detection. Statistical analysis showed no significant difference between growers' and technicians' levels of Rhizopus contamination (Table 1).

#### Petals dislodged from the medium

Six cooperators had petals that could not be examined for fungal infestation because they had dislodged from the medium (Table 1). Possible causes of dislodging include upside-down storage of plates, insufficient contact between the medium and petals, and the electrostatic attraction exerted by the plastic lids of culture plates. Indeed, all three conditions may have acted together. In any case, the occurrence of dislodged petals on growers' but not on technicians' plates indicates some deficiency of the kit, either in thoroughness of instructions or in the suggested procedure itself.

### EVALUATION

#### Profile of Cooperators

The personal data collected from cooperators revealed that the average grower in this study was 45 years old with 23 years of farming experience and a Grade 12 education with at least some post-secondary training. Nevertheless, the cooperators were by no means a homogenous group, ranging in ages from 19 to 71 and in education levels from Grade 8 to a Bachelor's degree plus Teaching Certificate (Figures 1 and 2).

The percentage of participants with Bachelor's degrees (29%) was noteworthy and comparison with 1981 Canada Census statistics on highest level of schooling revealed that, nationally, only 3% of workers on farms had university degrees. The discrepancies between the two samples is partly because Canada Census figures do not distinguish farm labourers from farm operators. The apparent bias in education levels in this study might also reflect the fact that it involved only willing and interested farm operators. This was done so that the objectives of the study might be met without complicating the results.

## Growers' Ages

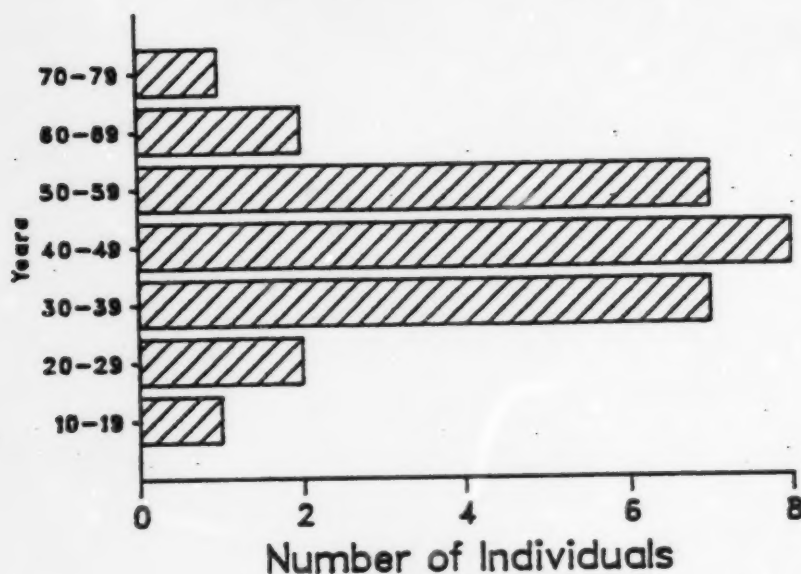


Figure 1: Histogram of growers' ages

## Growers' Education Levels

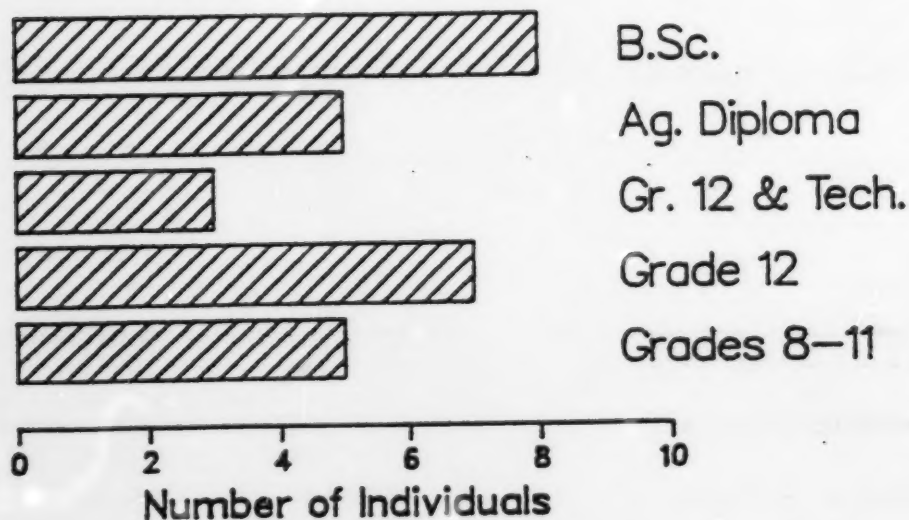


Figure 2: Histogram of growers' education levels

### Coordinator's Observations

Before the participants were approached, a list of potential problems with the procedure was drawn up so as to ensure that warnings addressing each anticipated problem were included with instructions. Nevertheless, problems arose that had not been foreseen, e.g. petals becoming dislodged from the medium. Such incidents were noted by the project coordinator and given special consideration in the composition of evaluative questions posed to cooperators. One such problem was the distribution of culture plates, some of which were contaminated with fungal growth prior to delivery. This appeared to be associated with excessive condensation inside the lids.

Six growers did not do the petal testing by themselves but delegated some or all of the procedure to an assistant. This was not unexpected. Questions asked in the interview sought to determine the nature and extent of participation by assistants.

At the time fields were sampled, most canola crops showed symptoms of blackleg and, in some cases, severe disease seemed imminent. Since there are as yet no registered chemicals for the control of blackleg on canola, the disease was not pointed out to growers. Questions were later posed that examined growers' awareness of this disease, and the fact that petal testing gives no indication of blackleg risk was discussed.

Finally, in the recording of results, whenever possible, the grower was shown sclerotinia in culture. This was done to facilitate discussion of growers' possible future involvement in reading results.

### Anonymous Questionnaire

Twenty-five of the 29 cooperators returned questionnaires; their responses are summarized in Table 2. Nine respondents experienced condensation and fungal contamination in unused plates. An average of 3 out of > 40 plates were affected in each of their kits. Three had excessive condensation but no visible contamination.

Of those who had videotapes, all found it a helpful addition although just over half believed it contained additional information not presented in the written instructions. Five respondents considered the procedure overly time-consuming. Only one said he would not use the kit if it was a commercial product costing about \$20 and including a service for reading results. Eighteen growers said that the kit should be commercialized.

Table 2: Responses of cooperators to an anonymous questionnaire concerning the suitability of the sclerotinia risk prediction kit.

|    |                                        | <u>yes</u> | <u>no</u> |                 |            |
|----|----------------------------------------|------------|-----------|-----------------|------------|
| I  | 1. Were all materials included?        | 25         | 0         |                 |            |
|    | 2. Was there excessive condensation?   | 12         | 13        |                 |            |
|    | 3. Were any plates contaminated?       |            |           |                 |            |
|    | If yes, how many?                      |            |           |                 |            |
|    | (1,12,2,2,1,3,4,1,1: Ave.=3.0)         |            |           |                 |            |
|    | 4. Were instructions easy to follow?   | 25         | 0         |                 |            |
|    | 5. Was video included?                 | 18         | 7         |                 |            |
| II | If yes, was it useful?                 | 18         | 0         |                 |            |
|    | Did it provide additional information? | 10         | 8         |                 |            |
|    | 1. Was procedure straightforward?      | 25         | 0         |                 |            |
|    | 2. Was it overly time-consuming?       | 5          | 20        | <u>improved</u> | <u>N/A</u> |
|    | 3. Should the kit be commercialized?   | 18         | 0         | 5               | 2          |
|    | 4. Would you buy it at \$20/field      | 24         | 1         |                 |            |

#### In-person Interviews

The responses to the in-person interview were more varied and complex. The major items of interest identified were as follows. About half of the participants had some problems with the materials, the most common being the presence of contaminated plates. Twenty-two participants felt that all the instructions were clear and seven felt that the video made the procedure clearer. Six growers felt that the time required for the test should be shortened. Fifteen said they would consider spraying for sclerotinia regardless of the petal test, but subject to a variety of conditions. Twenty-eight growers preferred the petal test to hunting for apothecia and 7 felt confident of the predictive capability of the test. Twenty-one growers had previous experience with blackleg but only 4 felt that blackleg affected the value of a petal test kit. Fourteen growers experienced a preference for "home testing" and 8 for "regional labs" in future petal testing. Of 22 growers who were shown sclerotinia in culture, 13 felt confident of their own ability to read results of the petal test in future. Sixteen respondents felt that growers themselves should read test results, if given the opportunity. These responses are discussed in more detail in the final section.



10  
DISCUSSION AND CONCLUSIONS

Suitability of the Petal Testing Procedure for Home Use

The answer to the question posed in the objective of this study is straightforward. The petal testing kit for predicting the risk of sclerotinia stem rot in canola is suitable for home use by growers. Aside from the constraints of climate and economics throughout the study, growers' results duplicated those of trained individuals. It is unfortunate that this study was unable to make this comparison over the full range of possible % petal infestations. Only minor modifications to instructions and quality control in production of materials appear necessary before a product based on the prototype kit could be commercialized.

The problem of petals dislodging from the medium in culture plates points out the need for a more explicit description of the plating technique, for example, "Push each petal onto the medium with the curved back of the forceps so it will stick." It should also be stated that plates should be stored top side up.

The contamination of culture plates before use is a problem that originated in their preparation. Consequently, the responsibility for correcting this problem lies with whoever might manufacture the kit. Inspecting culture dishes and discarding any that show significant condensation would be worthwhile. Most culture plates, left undisturbed, remained free of microbial growth for weeks. Regardless, culture plates should be prepared close to the time when they are required.

All kits were hand delivered to cooperators so the "transportability" of packaging and materials was not severely tested. Problems of disinfectant leakage and contaminated plates, and suggestions that the kits should have been more compact, indicate the importance of proper packaging. Ideally, materials should be packed to minimize empty space within the box so that individual items are not jostled during handling.

Some collecting bags issued with growers' kits were difficult to open. The bags currently used by produce vendors and in grocery stores, have proved much easier to open and should be used in future.

The time required for petal testing was a concern to some cooperators, especially those who were testing Polish canola flowers which are smaller and more delicate than Argentine. Unfortunately, neither the number of sampling sites nor the number of petals tested per site can be reduced without a significant increase in the error of estimation of XPI. The length of time an individual requires to complete testing varies depending on his dexterity. Participants who tested more than one field found repetitions took less time as they became more comfortable with the technique. Most cooperators took 1 - 1 1/4 h to complete testing for one field, excluding the time needed for collecting samples.

Acceptability of the Petal Testing Kit for Commercialization

Though the suitability of the kit for home use is evident, many other considerations beyond the scope of that question were raised by growers' evaluation as factors that might affect the acceptability of the kit as a commercial product.

The first is alternative methods for deciding whether or not to use chemical control. Nearly two thirds felt they would consider spraying without any indication of inoculum potential, albeit with some, mostly economic, reservations. One alternative for determining risk of sclerotinia stem rot is a forecasting system in which points are tallied from qualitative measures of crop history, potential yield, environmental factors, and the occurrence of apothecia in or near the crop. The simplicity of such risk prediction is certainly attractive. However, growers' feelings about hunting for apothecia testify to their doubts about their own ability to do it and its value in forecasting. The degree of reservation expressed concerning the predictive ability of petal testing reemphasizes the lure of alternative methods not based on estimation of inoculum potential.<sup>1</sup> It seems inevitable that a portion of canola growers would choose not to use the kit for this reason. Continued documentation of the effectiveness of petal testing in prediction would be a necessary prerequisite of commercialization.

Approximately half of the cooperators preferred the process of home testing to the other current option, taking samples to a regional laboratory. The biggest point of contention was who should be responsible for reading results if home testing became available. Many who had been shown sclerotinia in culture were confident that they could, in future, do the reading themselves. However, the desire for a second opinion in interpretation of results was expressed by some. The suggested alternatives to growers reading their own results did not point to one particular group. Many did state a concern that provision of such a service should be a vehicle for creating employment for students.

If reading were to be done by someone other than the grower, there exist several alternatives, yet to be studied, for doing so. The test plates could be brought by the grower to a central location. Technicians would be able to process many more samples than if they were setting up tests and reading results. A second option would be for growers to mail their plates to a central location. The probability of petal displacement in transit would be great. A third option would be for technicians to visit farms to read results. This would be the most convenient option for growers but the most costly to provide.

The cost of any of the alternatives for future developments in petal testing was brought up again and again by cooperators. Unquestionably, the cost of the kit and reading service must be more than offset by savings in expenditure on chemicals if spraying is ruled

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<sup>1</sup>a general indicator used by plant pathologists to signify quantity and quality of the infectious structures causing a disease.

out on the basis of low sclerotinia risk, or by returns on yield that might have been lost had chemical control not been implemented. The average size of field tested in this study was 100 acres. Even if the price of a commercial kit was to double the cost of materials and assembly (about \$40), the cost to the consumer would still be less than 50 cents per acre.

At current prices of registered fungicides (\$20/ac) and potential revenue generated by an average yield (\$120/ac), spraying cannot reasonably be considered unless projected yield losses are greater than about 20%. This calculation assumes complete effectiveness of chemical control. A realistic threshold, therefore, would be even higher, e.g. 25%. Since this level of yield loss is that projected from a 100% PI, it is not surprising that none of the cooperators considered chemical control. In years when either commodity prices or potential yields are higher, the threshold might be substantially lower and the inherent value of a kit for predicting risk of sclerotinia stem rot of canola would increase as a result.

Recommendations stemming from this study may be summarized as follows:

1. Instructions to prevent dislodging of petals should be included.
2. Plates should be prepared close to the time when they are needed and taking care to prevent condensation.
3. Kits should be packed to minimize damage during handling.
4. Collecting bags should be the kind treated for easy opening.
5. Research into the relationship between petal infestation levels and disease must continue.
6. Pictorial information on the symptoms of blackleg might be included with the kit.
7. A study of canola growers' ability to read, and interpret, results should be initiated.
8. A plate reading service should be offered as a part of a commercial kit until growers' ability to read results has been established.
9. The price of any commercial product arising from the prototype kit should be kept to a minimum, i.e. close to the cost of materials and assembly.

The benefits from the use of a petal testing kit would accrue to both those who would use it and those who might produce it. Canola growers would be able to reduce fungicide use, an economic saving and an ecological advantage. Prolonged or repeated use of a chemical control method places selective pressure on the pathogen. The benefit to the producer of the kit would be a greater credibility in making control recommendations and a better basis on which to do so.

Appendix E. Instructions for growers to set up petal tests, 1988.



## INSTRUCTIONS FOR SETTING UP YOUR OWN PETAL TEST

### I. Collecting Flowering Shoots

1. Check your fields periodically in order to anticipate the correct time for collecting. There are three different ways to decide when the crop is at early bloom and samples should first be collected. Briefly they are:
  - a. 4-6 days after first flowering
  - b. 20% bloom stage
  - c. growth stage 4.2 (See brochure entitled "Sclerotinia Project Year 4").
2. Collect samples at four, or preferably five sites per field. These sites should be at least 50 yards apart.
3. Do not collect samples too early in the morning, while it is raining, less than 4 hours after heavy rain, or less than two hours after light rain. The ideal time is between noon and 5:00 p.m. There is reason to suggest that collecting of inappropriate times will tend to underestimate disease risk.
4. The actual collecting is simple. At each site pick off 8-10 flowering shoots and place them loosely in a clean plastic bag. At early bloom the stems should still be tender and break off easily. Do not seal the bag; just close it loosely and write the date, time, and field number (if applicable) directly on the bag. Proceed to the next site and collect another 8-10 shoots, placing them in a separate bag. Repeat until you have taken shoots from each site.
5. Take the samples as quickly as possible to your home or wherever you will be setting up the test (next step). Do not crush the samples or leave them exposed to sunlight for any length of time.

### II. Testing Petals by Plating

1. Lay out the materials provided on a clean work surface. These include culture plates, empty plastic dishes, curved-tip forceps, disinfectant, and a marker pen.
2. Pour disinfectant into one of the empty dishes. Dip the forceps and wave them gently above the dish to air-dry.
3. Take a shoot from the sample bag for the first site. With the forceps, gently pull out one petal from each of 4-5 different flowers along the shoot. Try not to tear the petals or take other flower parts along with them. It may take a little practice, especially with the smaller, more delicate flowers of Polish varieties (Tobin). As you pick them, place the petals in an empty dish. Discard that shoot and take another. Continue in this manner until there are more than 40 petals in the dish.

4. Next, open a bag of 10 culture plates and lay them out in front of you. If any are visibly contaminated, discard them and replace with one from the bag of extra plates (see below). Dip and wave the forceps again. Place four petals spaced apart in each plate. Lift the edge of the dish only high enough to slip the petals onto the culture medium. Placing the petals with the blade flat on the medium surface and tips pointing up will ensure that they remain in place when the plates are handled. A small bag of extra culture plates is provided in case of contamination or accidents (example: dropping a plate on the floor).
5. Label each plate with the site number and field number (if applicable). Write your name on the top plate in the stack. Stack the 10 plates when 40 petals are in place.
6. Steps 3-5 are repeated with each of the samples from one field. Remember to disinfect the forceps, especially between samples from different sites.

### III. Storage and Delivery of Completed Plates:

1. Place the stacks on a shelf or in a cupboard that is clean, dry, and OUT OF DIRECT SUNLIGHT. Do not place the stacks back in the plastic bags until you are ready to deliver or send them to our lab.
2. Please inform us immediately if you are having problems with the materials, the instructions, or are unable to complete the procedure for whatever reason. Questions and comments will always be welcomed. Phone us at one of the numbers below.
3. The completed plates should be delivered to our lab within 3 1/2 days of being set up so that we may read the results for you. Before transporting the plates place each stack back in a separate plastic bag and tie it tightly. Make sure that during transportation the plates remain closed and right side up and are protected from damage. If you are shipping them by bus this may require some imaginative packing. If you deliver them yourself to our lab, please try to do so when staff are present. If you ship by bus, please phone to let us know they are on the way. For further information about where to deliver the plates, phone one of the following numbers: 752-3070 (Melfort); 966-4410 (Saskatoon); 236-4441 (Meadow Lake); 867-9931 (Outlook).

Appendix F. Unpublished manuscript by R.A.A. Morrall et al.

Morrall

SCLEROTINIA STEM ROT OF CANOLA IN WESTERN CANADA:

YIELD LOSSES AND ALTERNATIVE STRATEGIES FOR CHEMICAL CONTROL

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Morrall

Table 2. Control of sclerotinia stem rot of rapeseed in 1984 trials expressed as percentage efficacy of treatments\* compared with control achieved by application of the same fungicide at the recommended dose at crop growth stage\*\* 4.2 or 4.3.

| Fungicide   | Rate of Application<br>(kg a.i./ha) | Growth Stage<br>at Time of Application | Percentage Efficacy |        |         |         |         |
|-------------|-------------------------------------|----------------------------------------|---------------------|--------|---------|---------|---------|
|             |                                     |                                        | Test 8              | Test 9 | Test 10 | Test 12 | Test 13 |
| Benomyl     | 0.3                                 | 4.1                                    | -                   | -      | 62      | -       | -       |
| Benomyl     | 0.3                                 | 4.2                                    | -                   | -      | -       | -       | -       |
| Benomyl     | 0.3 + 0.3                           | 4.1 + 4.3                              | 108                 | 113    | -       | -       | 117     |
| Benomyl     | 0.3 + 0.3                           | 4.2 + 4.3                              | 118                 | -      | 138     | -       | -       |
| Vinclozolin | 0.3                                 | 4.1                                    | -                   | -      | -       | 79      | 131     |
| Vinclozolin | 0.3                                 | 4.2                                    | -                   | -      | 54      | -       | -       |
| Vinclozolin | 0.3 + 0.3                           | 4.1 + 4.3                              | 82                  | 38     | -       | -       | 100     |
| Vinclozolin | 0.3 + 0.3                           | 4.2 + 4.3                              | 115                 | -      | 80      | -       | -       |
| Iprodione   | 0.3                                 | 4.1                                    | -                   | -      | -       | 103     | 106     |
| Iprodione   | 0.3                                 | 4.2                                    | -                   | -      | 2       | -       | -       |
| Iprodione   | 0.3 + 0.3                           | 4.1 + 4.3                              | 56                  | 167    | -       | -       | 106     |
| Iprodione   | 0.3 + 0.3                           | 4.2 + 4.3                              | 122                 | -      | 58      | -       | -       |
|             |                                     |                                        |                     |        | -       | 109     | 106     |

\*See text for calculation of % efficacy.

\*\*Growth stages according to Harper and Berkenkamp (8).

Morrall

Table 3. Disease incidence of sclerotinia stem rot of rapeseed in relation to low doses and split applications of three fungicides at Meadow Lake, Saskatchewan in 1986.

| Treatment*  |             | Percentage of<br>Plants Infected |
|-------------|-------------|----------------------------------|
| July 8th    | July 18th   |                                  |
| No spray    | No spray    | 31.5a**                          |
| No spray    | Benomyl     | 25.0a                            |
| No spray    | Iprodione   | 18.1                             |
| No spray    | Vinclozolin | 11.7                             |
| Vinclozolin | No spray    | 11.6                             |
| Iprodione   | Iprodione   | 10.6b                            |
| Iprodione   | No spray    | 9.9b                             |
| Iprodione   | Benomyl     | 8.4b                             |
| Benomyl     | Iprodione   | 7.5c                             |
| Iprodione   | Vinclozolin | 7.4b                             |
| Benomyl     | Benomyl     | 7.0c                             |
| Benomyl     | Vinclozolin | 6.6c                             |
| Benomyl     | No spray    | 6.3c                             |
| Vinclozolin | Iprodione   | 5.9d                             |
| Vinclozolin | Benomyl     | 4.6d                             |
| Vinclozolin | Vinclozolin | 4.3d                             |

\*All fungicide applications made at 0.25 kg ai/ha.

\*\*Values followed by the same letter are not significantly different at  $p = 0.05$  according to orthogonal contrasts.

Appendix G. Abstract of thesis and report by S.V. Rude.

- G (i) - Abstract of thesis by S.V. Rude (to be submitted April 1989).
- G (ii) - Pesticide Research Report by S.V. Rude et al. (1987)

ABSTRACT

According to current recommendations, foliar fungicides for the control of sclerotinia stem rot in rapeseed should be applied at early or full bloom but not at late bloom. Field experiments were conducted in several areas of Saskatchewan in 1987 and 1988 to determine if spraying with benomyl at late bloom could adequately control the disease in at least some situations. The experiments were designed to determine if the growth stage at which inoculum of S. sclerotiorum first becomes widespread in the crop affects the efficacy of late bloom application. Rate of application and nozzle type were varied in a few tests.

Disease levels were high enough to warrant collection and analysis of disease incidence data at 4 of 5 locations in 1987 and 5 of 10 locations in 1988. Late bloom application of benomyl at the recommended rate (0.6 kg a.i./ha) significantly reduced disease incidence compared to the check in all tests except one. In four tests, disease reductions of  $\geq 80\%$  were achieved. Generally, higher levels of control were achieved when high levels of inoculum were not present in the crop until at least full bloom. In these situations the chemical was applied at approximately the same time that most infections were initiated. Application at 0.3 kg a.i./ha caused significant reductions in disease compared to the check at 3 of 4 locations, indicating that it may be possible to control stem rot adequately by spraying at less than the recommended rate. Significant



control was also achieved at 2 locations by spraying at 0.15 kg a.i./ha. There was limited evidence that small spray droplets generated by 11001 nozzles may improve control with benomyl.

The effect of time of infection (ie. plant growth stage) on yield loss was studied in growth chamber and field experiments. It was found that plants infected at late bloom suffer a significantly lower yield reduction than those infected earlier in the flowering period. In a field experiment, the yield reduction per plant was only 8% when high inoculum levels were not present until late bloom. More research is required in this area before fungicide application at late bloom can be considered an economically feasible option for rapeseed growers.

Finally, the disease incidence/disease severity (I-S) relationship for sclerotinia stem rot was studied using regression analysis. The slopes of regression equations were similar between years and, with the exception of one field, were similar among fields. This suggests that factors such as rainfall, stand density and inoculum levels have little effect on the I-S relationship. Fungicide application also did not appear to have an effect. The equation  $\text{disease severity} = 0 + 0.692 \times \text{disease incidence}$  described the overall relationship ( $R^2=95.5\%$ ). This could be used to predict severity from incidence data, at least within Brassica napus cv. Westar, thereby simplifying disease assessment.

CROP: Canola cv. Westar

PEST: *Sclerotinia sclerotiorum*

TITLE: EVALUATION OF LATE-BLOOM FUNGICIDE  
APPLICATION FOR THE CONTROL OF SCLEROTINIA  
STEM ROT IN CANOLA, 1987.

MATERIALS: BENLATE 50 WP (benomyl)

METHODS: Three fields in east-central Saskatchewan with moderate to heavy stands were selected. In field #1 and in field #2, apothecia were not observed until late-bloom and full-bloom respectively. In field #3 abundant apothecia were present from late-bud onward. Each trial was divided into 24 plots (2m x 5m). Twelve plots were sprayed (0.6 kg a.i./ha) at late bloom. The plots were paired so that a sprayed plot was always adjacent to a check plot. Treatments were applied with a hand applicator (R & D sprayer) at 400 l/ha. and 240 KPa using LF3 80° nozzles. Spray dates were July 9 for field #1 and July 17 for fields #2 and #3.

The trials were assessed for disease a few days before swathing. In fields #1 and #2, plants were pulled from 2 m<sup>2</sup> quadrats in each plot and the percentage of diseased plants was determined. In field #3 a 3 m<sup>2</sup> area was used because of a lower plant density.

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RESULTS: See table.

CONCLUSIONS: Fungicide application at late-bloom significantly reduced the amount of stem rot in all three fields. Excellent control was achieved when inoculum was not present until full-bloom or later but significant control was achieved even when inoculum was present at the onset of flowering. In field #3 control was less effective since many infections were probably already well developed at the time of application.

It is currently recommended that foliar fungicides to control stem rot should be applied no later than full-bloom. However it is possible to achieve effective control by spraying at late-bloom when the appearance of inoculum is delayed. This may provide a new option for canola growers.

|                                |         | Field #1         | Field #2         | Field #3          |
|--------------------------------|---------|------------------|------------------|-------------------|
| Percentage of diseased plants* | sprayed | 1.7 <sup>+</sup> | 4.2 <sup>+</sup> | 22.2 <sup>+</sup> |
|                                | check   | 16.8             | 24.5             | 36.4              |
| Percentage control **          |         | 90               | 83               | 39                |

\* all figures represent means of twelve replications

\*\*  $\frac{\text{check} - \text{sprayed}}{\text{check}} \times 100$

+ significantly different from check at P = 0.01 (paired t-test after angular transformation of data)

Appendix H. Pesticide Research Reports on fungicide application technology,  
1987-88.

- H - Report by R.A.A. Morrall and P.R. Verma (1987)
- H (i) - Report by R.A.A. Morrall and P.R. Verma (1988)
- H (ii) - Report by R.A.A. Morrall (1988)

**CROP:** Canola, cv. Westar

**PEST:** Stem rot, *Sclerotinia sclerotiorum* (Lib.) de Bary.

**TITLE:** APPLICATION TECHNOLOGY AND CONTROL OF SCLEROTINIA STEM ROT OF CANOLA WITH BENLATE, 1987.

**MATERIALS:** BENLATE 50 WP (benomyl)

**METHODS:** A commercial crop in east-central Saskatchewan was selected for the plots on the basis of a moderately good stand and the presence of abundant apothecia. The plots were set up and sprayed on July 8, when the crop was at early bloom. Treatments consisted of a non-factorial combination of two nozzle types, three fungicide dosages, two volumes of carrier fluid and three spray boom heights (see Table). All applications were made with a tractor-drawn sprayer, custom built and operated by Rogers Engineering Inc. of Saskatoon, Saskatchewan. The spray boom was mounted to one side of the tractor and variations in carrier volume were achieved by varying tractor speed and nozzle type. All treatments were applied at 300 KPa.

The plot design was a three-replicate randomized complete block, modified by the placement of a non-sprayed check in every fourth plot. Thus, in addition to 11 spray treatments each block contained three check plots. Each plot was 10 m x 2 m and separated from adjacent plots in the block by either a 1 m strip or a 4 m alleyway along which the tractor was driven.

On August 19-20, when the crop was nearing maturity, disease incidence was assessed by counting the percentage of infected plants in a sample of 200 plants from the centre of each plot. In two replicates, disease severity was also assessed, but since the results provided no additional insights, they are not presented here. The data were analyzed by ANOVA and Duncan's multiple range test.

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**RESULTS:** See table. Favorable weather for infection and disease development throughout July and August resulted in disease incidence values in the check plots of 30-40%. All 11 treatments resulted in a high level of control but there were few significant differences among specific spray treatments.

**CONCLUSIONS:** Under the conditions of this experiment Benlate gave good control of stem rot at 0.125 kg ai/ha (25% of the recommended dose), particularly with 11001 spray nozzles. There were no clear effects of spray boom length or carrier volume on efficacy of control. Although the differences were not significant, the treatments giving the three lowest disease incidence values were all applied with 11001 nozzles. Thus, there was an indication that small spray droplets generated by 11001 nozzles may improve control with Benlate. These and previous results (Morrall et al., 1984 P.R.R.) strongly suggest that further work is justified to develop application technology that will permit good control of stem rot with low fungicide doses and low carrier volumes.

Incidence of sclerotinia stem rot in relation to fungicide dose and method of application.

| Dose of Benlate (kg a.i./ha) | Volume of Carrier Fluid (L/ha) | Height of Spray boom above canopy* (cm) | Nozzle Type | Disease incidence ** |
|------------------------------|--------------------------------|-----------------------------------------|-------------|----------------------|
| 0 (check)                    | —                              | —                                       | —           | 35.6 a ***           |
| 0.125                        | 50                             | 10                                      | 8015        | 11.1 b               |
| 0.250                        | 100                            | 60                                      | 8015        | 7.8 bc               |
| 0.500                        | 50                             | 10                                      | 8015        | 6.2 bc               |
| 0.125                        | 100                            | 10                                      | 8015        | 6.1 bc               |
| 0.250                        | 100                            | 10                                      | 8015        | 5.2 bc               |
| 0.250                        | 50                             | 10                                      | 8015        | 5.2 bc               |
| 0.500                        | 100                            | 10                                      | 8015        | 4.0 bc               |
| 0.250                        | 100                            | 30                                      | 8015        | 3.5 bc               |
| 0.125                        | 50                             | 10                                      | 11001       | 3.0 bc               |
| 0.250                        | 50                             | 10                                      | 11001       | 2.2 bc               |
| 0.500                        | 50                             | 10                                      | 11001       | 1.2 c                |

\* Measured from the tips of the tallest inflorescences.

\*\* Means of 3 replications; check was the mean of 3 plots in each of 3 replications (n = 9)

\*\*\* Values followed by the same letter are not significantly different at p = 0.05 according to Duncan's multiple range test.



**CROP:** Canola cv. Westar

**PEST:** Stem rot, *Sclerotinia sclerotiorum*

**TITLE:** APPLICATION TECHNOLOGY AND CONTROL OF  
SCLEROTINIA STEM ROT OF CANOLA WITH ROVRAL,  
1987 AND 1988.

**MATERIALS:** ROVRAL 25F (iprodione)

**METHODS:** Commercial crops were selected for plots on the basis of moderate to good stands and the presence of apothecia. The plots were staked and sprayed in 1987 on July 8-9 near Melfort in E. Central Saskatchewan and in 1988 on July 7 near Meadow Lake in W. Central Saskatchewan. In 1987 the crop was at early bloom (Growth Stage 4.2) and in 1988 it was almost at full bloom (Growth Stage 4.2-4.3). In 1987 the treatments consisted of a non-factorial combination of two nozzle types, three fungicide dosages, two volumes of carrier fluid and three spray boom heights (see Table). In 1988 two nozzle types, two fungicide dosages, two carrier volumes and two boom heights were tested. All treatments were applied in both years at 300 kPa. Application was done by Rogers Engineering Inc. of Saskatoon, Saskatchewan using custom built sprayers mounted on a tractor with the spray boom on one side. Variations in carrier volume were achieved by varying tractor speed and nozzle type.

In both years the plot design was a 3-replicate RCBD. In 1987 this was modified by the addition of a non-sprayed check in every fourth plot. Thus, in addition to 11 treatments, each block contained 3 check plots. In 1988 there were only 5 treatments and one check per block. All plots were 10 m x 2 m. In 1987 the plots were separated from adjacent plots in the block by either a 1 m strip or a 4 m pathway along which the tractor was driven. In 1988 plots were separated by a 3 m pathway. Replicate blocks were separated from each other by 5 m strips in 1987 and 10 m strips in 1988.

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Disease incidence was assessed in the plots when the crops were near maturity (August 19-20, 1987 and August 23, 1988). The percentage of infected plants was counted in a sample of 200 plants from the centre of each plot. The data were arcsin transformed and analysed by ANOVA and Duncan's multiple range test.

**RESULTS:** See Table. In 1987 favorable weather for infection and disease development throughout July and August resulted in disease incidence values in the check plots of 30-40%. However in 1988 disease development was less than expected and ranged from 6 to 27% in the check plots. Although there was a highly significant effect of treatment on disease incidence in 1987, many treatments were not significantly different from the check (see Table). In 1988 there were no significant differences among the treatments.

**CONCLUSIONS:** These tests were, perhaps, limited by the fact that there were only three replicates and that in 1988 disease pressure was low. However, in 1987 the only treatments that were significantly different from the check were the three involving application of the fungicide at 0.5 kg ai/ha (see Table), which is at the lower end of the range recommended by the manufacturer. Moreover the level of control in these treatments was from 59% to 60%. Thus, there is little evidence that a high level of control could be achieved with low doses of Rovral by manipulating methods of application.

Incidence of sclerotinia stem rot in relation to fungicide dose and method of application

| Dose of<br>Rovral<br>(kg a.i./ha) | Volume of<br>Carrier Fluid<br>(L/ha) | Height of<br>Spray Boom<br>Above Canopy*<br>(cm) | Nozzle type | Disease<br>Incidence**<br>1987 | Disease<br>Incidence<br>1988 |
|-----------------------------------|--------------------------------------|--------------------------------------------------|-------------|--------------------------------|------------------------------|
| 0 (check)                         | -                                    | -                                                | -           | 32.1a***                       | 14.8                         |
| 0.250                             | 100                                  | 10                                               | 80015       | 26.5a                          | 12.2                         |
| 0.125                             | 100                                  | 10                                               | 80015       | 25.3ab                         | n/a                          |
| 0.125                             | 50                                   | 10                                               | 11001       | 24.0ab                         | n/a                          |
| 0.250                             | 100                                  | 30                                               | 80015       | 21.7ab                         | n/a                          |
| 0.125                             | 50                                   | 10                                               | 80015       | 21.0ab                         | n/a                          |
| 0.250                             | 50                                   | 10                                               | 11001       | 19.7ab                         | 5.1                          |
| 0.250                             | 100                                  | 60*                                              | 80015       | 19.2ab                         | n/a                          |
| 0.500                             | 100                                  | 50                                               | 80015       | n/a                            | 5.1                          |
| 0.250                             | 50                                   | 10                                               | 80015       | 18.3ab                         | n/a                          |
| 0.500                             | 50                                   | 10                                               | 11001       | 13.0b                          | 6.8                          |
| 0.500                             | 50                                   | 10                                               | 80015       | 11.3b                          | n/a                          |
| 0.500                             | 100                                  | 10                                               | 80015       | 10.8b                          | 9.2                          |

\*Measured from the tips of the tallest inflorescences.

\*\*Mean of 3 replications; check was mean of 3 plots in each of 3 replications (n=9).

\*\*\*Values followed by same letter not significantly different at p=0.05 according to Duncan's multiple range test.

**CROP:** Canola, cv. Westar

**PEST:** Stem rot, *Sclerotinia sclerotiorum*

**TITLE:** LOW VOLUME AND LOW DOSE APPLICATIONS OF BENLATE TO CONTROL SCLEROTINIA STEM ROT OF CANOLA, 1988.

**MATERIALS:** BENLATE 50WP (benomyl).

**METHODS:** A commercial crop at Meadow Lake, in west-central Saskatchewan was selected for the plots on the basis of a good stand, the presence of apothecia and petal infestation with *Sclerotinia*. The plots were staked and sprayed on July 7 and July 8 when the crop was almost at full bloom (Growth Stage 4.2-4.3). Treatments consisted of a non-factorial combination of five nozzle types, three spray pressures, six fungicide dosages and five carrier fluid volumes with a non-sprayed check (see Table). Application was done by Rogers Engineering Inc. of Saskatoon, Saskatchewan using a custom-built sprayer mounted on a tractor with the spray boom at one side. Variations in carrier volume were achieved by varying tractor speed, pressure and nozzle type. All applications were made with the boom set 35 cm above the top of the crop canopy.

The plot design was a three-replicate RCBD. Each plot was 10 m x 2 m and separated from adjacent plots by a 3 m pathway in which the tractor was driven. Replicate blocks were separated from each other by 10 m strips.

On August 23, when the crop was near maturity, disease incidence was assessed by counting the percentage of infected plants in a sample of 200 plants from the centre of each plot. The data were

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subjected to arcsin transformation before analysis of variance. Specific contrast comparisons were made and Duncan's multiple range test was also applied.

**RESULTS:** See Table. Disease development was less than expected considering the inoculum load during flowering. Disease incidence ranged from 11 to 23% in the check plots. The contrast check vs. other treatments was highly significant and most treatments gave good control. When treatments with different combinations of nozzle type + carrier volumes were compared, only the contrast of 800040 with other nozzle types was significant. The contrast of all treatments at 0.125kg ai/ha with all those at 0.250kg ai/ha was significant, but the contrast between 0.250kg ai/ha and 0.500kg ai/ha was not.

**CONCLUSIONS:** Because of low disease pressure in this test and the small number of replications only tentative conclusions may be drawn. With most combinations of nozzle type, pressure and carrier volume disease incidence was inversely proportional to fungicide dose. However, good control occurred with doses of 0.25 kg ai/ha in several cases. Treatments 4-15 all involved lower volumes of carrier fluid than commonly used by growers and all except 7 gave control similar to that achieved with higher volumes. Of particular interest is the excellent control achieved in two cases with only 10 L carrier fluid/ha by using 800017 nozzles and 552 kPa pressure. Further work is clearly necessary.

Incidence of sclerotinia stem rot in relation to fungicide dose and method of application

| Treatment  | Nozzle type | Spray pressure (kPa) | Dose of Benlate (kg a.i./ha) | Volume of carrier fluid (L/ha) | % disease incidence | % control* |
|------------|-------------|----------------------|------------------------------|--------------------------------|---------------------|------------|
| 1          | 80015       | 297                  | 0.125                        | 105                            | 5.5bc**             | 67%        |
| 2          | 80015       | 297                  | 0.250                        | 105                            | 3.5bc               | 79%        |
| 3          | 80015       | 297                  | 0.500                        | 105                            | 1.8c                | 89%        |
| 4          | 800067      | 297                  | 0.125                        | 50                             | 5.2bc               | 69%        |
| 5          | 800067      | 297                  | 0.250                        | 50                             | 3.8bc               | 77%        |
| 6          | 800067      | 297                  | 0.500                        | 50                             | 3.6bc               | 79%        |
| 7          | 800040      | 414                  | 0.125                        | 27                             | 15.7a               | 7%         |
| 8          | 800040      | 414                  | 0.250                        | 27                             | 5.8bc               | 65%        |
| 9          | 800040      | 414                  | 0.500                        | 27                             | 2.3c                | 86%        |
| 10         | 1100025     | 552                  | 0.175                        | 15                             | 4.7bc               | 72%        |
| 11         | 1100025     | 552                  | 0.350                        | 15                             | 8.5ab               | 49%        |
| 12         | 1100025     | 552                  | 0.700                        | 15                             | 4.0bc               | 76%        |
| 13         | 800017      | 552                  | 0.125                        | 10                             | 5.2bc               | 69%        |
| 14         | 800017      | 552                  | 0.250                        | 10                             | 1.7c                | 90%        |
| 15         | 800017      | 552                  | 0.500                        | 10                             | 2.2c                | 87%        |
| 16 (check) | -           | -                    | -                            | -                              | 16.8a               | -          |

\*Determined as (Check-Treatment/Check) x 100.

\*\*Values followed by same letter not significantly different at  $p=0.05$  according to Duncan's multiple range test.

Appendix I. Pesticide Research Reports on Fungicides to control sclerotinia,  
1986-88.

- I - Report by P.R. Verma et al. (1986)
- I (i) - Report by P.R. Verma et al. (1987)
- I (ii) - Report by D.L. McKenzie et al. (1988)

**CROP:** Canola cv. Triton (*Brassica napus* L.)

**PEST:** Sclerotinia stem rot, *Sclerotinia sclerotiorum*

**TITLE:** EFFICACY OF FOLIAR-APPLIED FUNGICIDES IN  
CONTROLLING SCLEROTINIA STEM ROT IN  
CANOLA-1986

**MATERIALS:** BENLATE 50 WP (benomyl), ROVRAL 25 WP (iprodione), EASOUT 70 WP (thiophanate-methyl), RONILAN 50 FL (vincozolin), PROCHLORAZ 40 EC (imidazole), PROCHLORAZ 40 EC + ENHANCE SURFACTANT, XE7791 25 FL (diniconazole) and DPX965 50 WP (carbendazim).

**METHODS:** The test site was chosen in a field in northwest Saskatchewan in mid-July on the basis of growth stage, uniform stand, presence of apothecia, and high percentage of *Sclerotinia*-infested petals. When the crop was at GS4.1 (July 20), 6m x 2m plots were established in a randomized complete block design with four replications. Fungicides were then applied to the foliage with an R + D plot sprayer at 276 Kpa and 416 l/ha.

At maturity, 200 plants from each plot were assessed for stem infection. Plants were grouped into five disease categories and the overall disease intensity was expressed as a "percent disease rating". This was calculated following the procedure reported in the 1982 Pesticide Research Report, p. 238. Analysis of variance was carried out and significant differences among means determined using Duncan's Multiple Range Test (DMRT).

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**RESULTS:** See table below.

**CONCLUSIONS:** Percent disease ratings of plants sprayed with BENLATE, DPX 965, EASOUT, ROVRAL, and RONILAN were significantly less than those in the non-sprayed check. PROCHLORAZ at 500 and 375 g a.i./ha was effective only in combination with the surfactant. XE 7791 was not effective at any of the rates tested.

| FUNGICIDE               | TREATMENT RATE<br>(g a.i./ha) | MEAN PERCENT<br>DISEASE RATING |
|-------------------------|-------------------------------|--------------------------------|
| BENLATE                 | 500                           | 4.0 <sup>a</sup>               |
| DPX 965                 | 500                           | 4.4 <sup>a</sup>               |
| ROVRAL                  | 500                           | 8.5 <sup>abc</sup>             |
| EASOUT                  | 1000                          | 6.3 <sup>a</sup>               |
| EASOUT                  | 750                           | 8.5 <sup>abc</sup>             |
| ROVRAL + EASOUT         | 250 + 250                     | 3.9 <sup>a</sup>               |
| RONILAN                 | 500                           | 6.4 <sup>a</sup>               |
| PROCHLORAZ + ENHANCE    | 500 + 250 ml (Product)        | 4.7 <sup>a</sup>               |
| PROCHLORAZ + ENHANCE    | 375 + 250 ml (Product)        | 7.8 <sup>ab</sup>              |
| PROCHLORAZ + ENHANCE    | 250 + 250 ml (Product)        | 14.9 <sup>bcd</sup>            |
| PROCHLORAZ              | 500                           | 15.1 <sup>bcd</sup>            |
| PROCHLORAZ              | 375                           | 22.4 <sup>de</sup>             |
| PROCHLORAZ              | 250                           | 16.0 <sup>cde</sup>            |
| XE7791                  | 150                           | 16.9 <sup>de</sup>             |
| XE7791                  | 100                           | 22.3 <sup>de</sup>             |
| XE7791                  | 50                            | 23.0 <sup>e</sup>              |
| CHECK                   | —                             | 20.9 <sup>de</sup>             |
| Standard Error of Means |                               | 2.3                            |

\* Values suffixed by the same letter(s) are not significantly different at the 5% level as determined by DMRT.



**CROP:** Canola cv. Westar (*Brassica napus* L.)

**PEST:** *Sclerotinia* stem rot, *Sclerotinia sclerotiorum*

**TITLE:** EVALUATION OF FOLIAR-APPLIED FUNGICIDES FOR THE CONTROL OF *SCLEROTINIA* STEM ROT IN CANOLA - 1987.

**MATERIALS:** Benlate 50 WP (benomyl), Easout 50 ULV (thiophanate-methyl), Rovral 25 FL (iprodione), Ronilan 50 FL (vinclozolin), Sportak (Prochloraz 40 EC) Sportak + Enhance Surfactant, PP 523 (hexaconazole 5% granular), PP 450 25 EC (flutriafol), DPX 965 50 DF (carbendazim) and TBZ 45 FL.

**METHODS:** The trial was conducted in two commercial fields in east-central Saskatchewan (Melfort, Carrot River) chosen on the basis of uniform stand, growth stage and presence of apothecia of *Sclerotinia sclerotiorum*. The treatment plots (6 m x 2 m) were established in a randomized complete block design with four replications. Foliar application with fungicides was made on July 6 (growth stage 4.1) by using an R.D. Plot Sprayer at 276 kPa and 416 L/ha. Disease assessment was done on August 18 when plants were at growth stage 5.2. At one location (Carrot River), where infection was low only the total number of infected plants (200 plants/plot) were recorded. At the second location (Melfort), 200 plants from each treatment plot were pulled

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and assessed for stem infection by categorizing them into 3 disease categories with 1 and 5 being the healthy and severe categories respectively. The overall disease intensity expressed as "percent disease rating" was calculated following the procedure reported previously (Pesticide Research Report, 1982, p. 238). Analysis of variance was carried out and significant differences between means determined by using Waller-Duncan's K-ratio t-test.

**RESULTS:** See table below.

**CONCLUSIONS:** Except PP 450, single applications of all other fungicides significantly reduced both percent infected plants and percent disease ratings when compared with the non-sprayed check. Among the fungicides both Benlate formulations, DPX 965 and Easout reduced the disease most and PP 523 the least.

| Fungicide               | Treatment Rate<br>(g a.i./ha) | % Infected<br>Plants* | % Disease Rating<br>Location 2** |
|-------------------------|-------------------------------|-----------------------|----------------------------------|
| Benlate WP              | 500                           | 1.4 <sup>***</sup>    | 0.8 <sup>a</sup>                 |
| Benlate DF              | 500                           | 2.9 <sup>a</sup>      | 1.1 <sup>a</sup>                 |
| DPX 965                 | 500                           | 1.4 <sup>a</sup>      | 1.2 <sup>a</sup>                 |
| Easout                  | 750                           | 4.9 <sup>a</sup>      | 4.2 <sup>ab</sup>                |
| Rovral                  | 500                           | 12.9 <sup>b</sup>     | 7.0 <sup>bc</sup>                |
| Ronilan                 | 500                           | 11.9 <sup>b</sup>     | 10.5 <sup>cd</sup>               |
| TBZ                     | 750                           | 12.3 <sup>b</sup>     | 10.9 <sup>cd</sup>               |
| Sportak                 | 300                           | 20.5 <sup>c</sup>     | 13.0 <sup>de</sup>               |
| Sportak + Enhance       | 500 + 250 ml (Product)        | 19.3 <sup>c</sup>     | 13.6 <sup>de</sup>               |
| Sportak                 | 400                           | 20.6 <sup>c</sup>     | 14.1 <sup>de</sup>               |
| Sportak + Enhance       | 300 + 250 ml (Product)        | 22.7 <sup>c</sup>     | 14.5 <sup>de</sup>               |
| Sportak                 | 500                           | 20.1 <sup>c</sup>     | 15.0 <sup>e</sup>                |
| Sportak + Enhance       | 400 + 250 ml (Product)        | 22.2 <sup>c</sup>     | 16.2 <sup>e</sup>                |
| PP 523                  | 250                           | 24.5 <sup>c</sup>     | 17.5 <sup>e</sup>                |
| PP 450                  | 250                           | 43.7 <sup>d</sup>     | 33.3 <sup>f</sup>                |
| Check                   | -                             | 34.1 <sup>d</sup>     | 25.6 <sup>f</sup>                |
| Standard error of means |                               | 2.22                  | 1.92                             |

\* Mean of two tests; \*\* Results of one test.

\*\*\* Within column means suffixed by the same letter are not significantly different at the 5% level as determined by Waller-Duncan's K-ratio t-test.

**CROP:** Canola (*Brassica napus* L.) cv. Westar

**PEST:** *Sclerotinia* Stem Rot, *Sclerotinia sclerotiorum*

**TITLE:** EFFICACY OF FOLIAR APPLIED FUNGICIDES FOR CONTROL OF *SCLEROTINIA* STEM ROT IN CANOLA

**MATERIALS:** BENLATE 50 WP (benomyl), ROVRAL 25 FL (iprodione), RONILAN 50 FL (vinclozolin), HWG 1608 1.2 EC, EASOUT 50 ULV (thiophanate-methyl), MERTECT 45 FL (thiabendazole), SAN 619 100 SL (cyproconazole 10%), SPORTAK 40 EC (prochloraz), ENHANCE (surfactant)

**METHODS:** Two test sites were established in growers' fields in northwest Saskatchewan (Meadow Lake area). Criteria for selecting these fields were uniform stand, presence of apothecia of *S. sclerotiorum* in the fields or in adjacent fields, and a high level of *Sclerotinia* infestation of the flower petals. The

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test sites consisted of 6 m x 2 m plots arranged in a 4-replicate RCB design. Foliar application of the fungicides was done at crop growth stage 4.2 using a R & D plot sprayer at 276 kPa and 416 L solution/ha. The number of infected plants/200 were counted at crop growth stage 5.2 at both test sites. Analysis of variance for 2 infection and Waller Duncan's k ratio t-test on treatment means were done.

**RESULTS:** See table below.

**CONCLUSIONS:** All treatments except SAN 619 at 80 g ai/ha significantly reduced the incidence of infection when compared to the untreated check.

| Fungicide                      | Rate<br>(g a.i./kg seed) | Mean %<br>Infected Plants* |
|--------------------------------|--------------------------|----------------------------|
| SPORTAK + ENHANCE              | 500 + 250 ml P           | 8.7 a**                    |
| EASOUT                         | 750                      | 9.3 a                      |
| ROVRAL                         | 500                      | 9.4 ab                     |
| BENLATE                        | 500                      | 10.8 abc                   |
| RONILAN                        | 500                      | 11.1 abc                   |
| MERTECT                        | 750                      | 12.3 abc                   |
| SPORTAK + ENHANCE              | 400 + 250 ml P           | 12.4 abc                   |
| HWG 1608                       | 150                      | 12.9 abcd                  |
| MERTECT                        | 500                      | 13.9 abcd                  |
| HWG 1608                       | 100                      | 14.2 abcd                  |
| SAN 619                        | 150                      | 15.9 bcd                   |
| MERTECT                        | 250                      | 16.6 cd                    |
| SAN 619                        | 80                       | 19.4 de                    |
| Check                          | —                        | 25.4 e                     |
| Pooled Standard Error of Means |                          | 2.2                        |

\* data from the 2 sites combined

\*\* means within a column followed by the same letter are not significantly different according to Waller Duncan's k ratio t-test (P = 0.05)

Appendix J. Abstract of thesis by K. Xi (1987)

Appendix J

EFFICACY OF FOLIAR-APPLIED FUNGICIDES  
AGAINST LEPTOSPHAERIA MACULANS (Desm.) Ces. & de Not.  
ON RAPESEED

A Thesis

Submitted to the College of Graduate Studies and Research  
in Partial Fulfilment of the Requirements  
for the Degree of  
Master of Science  
in the  
Department of Biology

by

Kequan Xi  
Saskatoon, Saskatchewan  
March, 1987

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# ABSTRACT

The efficacy of foliar applications of fungicides to control Leptosphaeria maculans on rapeseed (Brassica napus cv. Westar) was evaluated in laboratory, greenhouse and field experiments during 1985-86. In the first part of the study, several compounds including Tilt, Captan and Sportak showed considerable potential in vitro against the pathogen in tests on mycelial inhibition, spore germination and sporulation. The mycelial growth test was used to compare five isolates of L. maculans in relation to five fungicides. A differential response to Maneb and Bravo between virulent isolates and one weakly virulent isolate was observed. In greenhouse experiments Bravo, Rovral and Sportak were tested against leaf lesions on plants at the seedling stage. Sportak at 300 ppm and Rovral at 500 ppm applied close to the date of inoculation showed more effective control of leaf lesions than lower concentrations.

In a field experiment with single applications of fungicides at Melfort in 1985, Rovral applied at the early bud stage at 750 g ai/ha significantly reduced disease and increased the yield by 28% over the check. In a similar experiment in 1986 no significant differences were found between two rates of applications of Rovral and Sportak. In experiments on spray dates, multiple applications of fungicides usually reduced disease more than single applications. With respect to timing, a single application at the mid-flowering stage gave significantly higher disease than applications at the early bud or late bud stage. However, no significant differences were detected between the effects of spraying at the rosette and at the early

flowering stages with either single or dual applications. Overall, Sportak generally showed more potential against the disease than any other fungicides.

Even though some fungicide treatments reduced disease significantly compared with checks, disease levels were still high and a significant yield increase occurred only in one experiment. Thus, it appears that the treatments tested gave inadequate control of the disease and none can be recommended for commercial practice.

Relationships between disease incidence (% infected plants) and severity (an index based on the % of plants in different disease categories) in field data were analyzed by regression. Similar parameters of the regression equations within each year were obtained. This suggests that location, disease level and environmental factors did not affect the I-S relationship of blackleg disease. However, significant differences in the slopes of the regression equations between the two years suggest influences on the relationship of either the different people involved in disease assessment each year and/or different fungicide treatments. General regression equations derived from combined data from each year could be used to predict severity from incidence only if the same fungicide and observers were used.

Appendix K. Pesticide Research Reports on 1987 experiments on foliar fur application to control blackleg.

- K - Report by R.A.A. Morrall et al. (1988 a)
- K (i) - Report by R.A.A. Morrall et al. (1988 b)

**CROP:** Canola, cv. Westar and cv. DN 188

**PEST:** Blackleg, *Leptosphaeria maculans*

**TITLE:** EVALUATION OF SINGLE AND MULTIPLE APPLICATIONS OF PROCHLORAZ AGAINST BLACKLEG OF CANOLA, 1987.

**MATERIALS:** SPORTAK 400 g ai/h (prochloraz) + ENHANCE SURFACTANT

**METHODS:** Plots were seeded at Saskatoon on May 20 on land with infested canola residues from 1985 to act as natural inoculum. A 6-replicate 2x8 factorial experiment with a split-plot design was used. The main plot effect was cultivar and the sub-plot effect was all possible combinations of fungicide applications on three consecutive spray dates about one week apart (see Table). Each sub plot was 12 rows, 4.9 m long and with 18 cm row spacing. Seeding was done with a small-plot tractor-drawn seeder and the 1.2 m space between blocks was seeded to barley to maintain a uniform microclimate in the plots. The plots were irrigated at about one week intervals according to weather conditions from June 15 until the end of July.

Spraying was done with a Model G3 R and D hand-held sprayer using LF3 80° nozzles and 242 kPa pressure. Each application was made at 400 g ai/ha prochloraz in 410 l water/ha with the surfactant Enhance at 250 ml product/ha. Spray dates were June 16, June 22 and July 2, representing growth stages 2.4, 3.1 and 4.1 respectively for both cultivars. The plots were harvested when close to maturity, i.e. August 13 for Westar and August 21 for DN 188. Plants from 2 m<sup>2</sup> in the centre of each plot were pulled and categorized according to the extent of blackleg stem lesions. The frequency of plants in each category was used to calculate percentage disease severity per plot (see Table). The plants from the 2 m<sup>2</sup> areas were dried and combined and the seed was cleaned and weighed to determine yields. ANOVA was performed on disease incidence (% diseased plants) values after arcsin transformation, disease severity values and yield. Where appropriate, specific contrast comparisons were made.

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**RESULTS:** See Table. Severe blackleg developed throughout the plots and induced premature ripening, especially in Westar. ANOVA showed highly significant effects of cultivar and spraying on disease incidence and severity. Only cultivar significantly affected yield, probably because the effect of spraying on disease was limited. In all sprayed plots combined, disease severity was reduced compared with the non-sprayed check by 11% in Westar and 15% in DN 188. The reductions from triple applications were 20% and 23% respectively. Specific contrasts indicated significant differences in the non-sprayed check vs. the sprayed plots and in one or two sprays vs. three sprays for both disease incidence and disease severity. The contrasts of treatment 5 vs 6+7 and treatment 6 vs 7 (see Table) were significant only for disease incidence. The contrasts suggest that later sprays slightly reduced infection and, therefore, disease incidence. However, they had no effect on the spread of previously established lesions which eventually had the most effect on disease severity because of weighting in the disease rating scheme.

**CONCLUSIONS:** Previous work (Xi K. 1987. M.Sc. thesis, Univ. Saskatchewan) had indicated significant, but limited, reductions of blackleg in Westar canola from one to three applications of prochloraz. In this test triple applications again gave limited control, even in a cultivar less susceptible than Westar and when the first application was made at an early growth stage. This and other studies, as well as economic considerations suggest very limited potential at present for controlling blackleg in western Canada by foliar fungicide application.

Effect of 1 to 3 applications of prochloraz on blackleg disease\* and yield in two canola cultivars

| Treatment Number | Total dose (g.ai/ha) | Growth stages on dates** of spraying |     |     | Westar              |                    |                | DN188               |                    |                |
|------------------|----------------------|--------------------------------------|-----|-----|---------------------|--------------------|----------------|---------------------|--------------------|----------------|
|                  |                      | 2.4                                  | 3.1 | 4.1 | % Disease incidence | % Disease severity | Yield (g/plot) | % Disease incidence | % Disease severity | Yield (g/plot) |
| 1                | 0                    | -                                    | -   | -   | 98.6                | 72.9               | 227            | 71.9                | 38.6               | 464            |
| 2                | 400                  | +                                    | -   | -   | 96.1                | 66.1               | 237            | 63.9                | 31.9               | 518            |
| 3                | 400                  | -                                    | +   | -   | 94.5                | 68.0               | 275            | 65.2                | 37.1               | 494            |
| 4                | 400                  | -                                    | -   | +   | 96.6                | 70.2               | 254            | 64.2                | 30.8               | 501            |
| 5                | 800                  | +                                    | +   | -   | 94.1                | 64.1               | 216            | 66.1                | 36.0               | 511            |
| 6                | 800                  | +                                    | -   | +   | 95.9                | 67.6               | 261            | 60.3                | 33.0               | 522            |
| 7                | 800                  | -                                    | +   | +   | 90.7                | 62.1               | 366            | 57.2                | 31.1               | 516            |
| 8                | 1200                 | +                                    | +   | +   | 89.4                | 58.5               | 320            | 56.0                | 29.6               | 512            |

\*Disease severity determined by categorizing plants as follows: 0 = No lesions on stem; 1 = Lesions on one side of the stem; 2 = More than 1/2 of stem circumference girdled by lesions; 3 = More than 1/2 of stem girdled, plant prematurely ripened but seeds healthy; 4 = Plant prematurely ripened and pods shrunk. Disease severity of plot = [(% #1 plants) + (2 x % #2 plants) + (3 x % #3 plants) + (4 x % #4 plants)] / 4

\*\*Spray dates: 2.4 (June 16); 3.1 (June 22); 4.1 (July 2)



**CROP:** Canola, cvs. Westar, DN 188, and Global

**PEST:** Blackleg, *Leptosphaeria maculans*

**TITLE:** EVALUATION OF FLUTRIAFOL AS A FOLIAR FUNGICIDE AGAINST BLACKLEG OF CANOLA, 1987

**MATERIALS:** IMPACT (ICIA450) 12.5 SC (flutriafol)

**METHODS:** Plots were seeded at Saskatoon on May 20 on land with infested canola residues from 1985 to act as natural inoculum. A 6-replicate factorial experiment with a split-plot design was used with cultivar as the main plot effect and a non-sprayed check or three dates of single application as the sub-plot effect. Each sub plot was 12 rows, 4.9 m long and with 18 cm row spacing. Seeding was done with a small-plot tractor-drawn seeder and the 1.2 m space between replicate blocks was seeded to barley to maintain a uniform microclimate in the plots. The plots were irrigated at about one week intervals according to weather conditions from June 15 until the end of July.

Spraying was done with a Model G3 R & D hand-held sprayer using LF3 80° nozzles and 242 kPa pressure. Applications were made at 250 g a.i./ha in 410 l water/ha and were timed to be at either growth stage (GS) 2.4, GS 3.1 or GS 4.1. The first and second spray dates were June 16 and June 22, respectively, for all cultivars; the third was July 2 for Westar and DN 188, but July 11 for Global.

The plots were harvested according to stage of maturity, which was affected by disease severity. Westar was harvested on August 13, DN 188 on August 21 and Global on August 28. Plants from 2 m<sup>2</sup> in the centre of each plot were pulled and categorized according to the extent of blackleg stem lesions. The frequency of plants in each category was used to calculate percentage disease severity per plot (see Table). The plants from the 2 m<sup>2</sup> areas were dried and combined and the seed was cleaned and weighed to determine yields. ANOVA was performed on disease incidence (% diseased plants) values after arcsin transformation, disease severity values and yield. Where appropriate, specific contrast comparisons were made.

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**RESULTS:** See Table. Severe blackleg developed throughout the plots, especially on Westar and DN 188. Although DN 188 and Westar mature within two days of each other under disease-free conditions, in this test Westar ripened at least one week earlier. ANOVA showed highly significant effects of cultivar on disease incidence, disease severity and yield. However, specific contrasts showed no significant difference between Global and DN 188 in disease incidence or severity. Effects of spraying flutriafol were extremely limited. There was no effect on yield and the only significant contrast in disease incidence or severity was between the check and the combined sprayed plots. The average percentage reduction in disease severity from spraying was 2 in Westar, 5 in DN 188 and 15 in Global.

**CONCLUSIONS:** The test mainly illustrated the dramatic effect of blackleg on yield. Under disease-free conditions Westar and DN 188 usually have similar yields, but in this test DN 188 outyielded Westar by 88%. Disease severity in Westar was 89% higher than in DN 188. The differentials in disease incidence and severity might have been higher if all cultivars had been harvested on the same date. However, yield differentials would have been reduced because of immature seed or losses from shattering. Under heavy disease pressure a single application of flutriafol did not give adequate control of blackleg, although this fungicide has been shown to have in vitro activity on *Leptosphaeria maculans*. Possibly application earlier in the growing season would have been more beneficial.

Effect of flutriafol at 250 g a.i./ha on blackleg disease\* and yield in three canola cultivars

| Growth stage<br>at time<br>of spraying | Westar                 |                       |                   | DN 188                 |                       |                   | Global                 |                       |                   |
|----------------------------------------|------------------------|-----------------------|-------------------|------------------------|-----------------------|-------------------|------------------------|-----------------------|-------------------|
|                                        | % Disease<br>Incidence | % Disease<br>Severity | Yield<br>(g/plot) | % Disease<br>Incidence | % Disease<br>Severity | Yield<br>(g/plot) | % Disease<br>Incidence | % Disease<br>Severity | Yield<br>(g/plot) |
| - (Check)                              | 98.3                   | 70.4                  | 238               | 71.2                   | 38.0                  | 493               | 64.8                   | 29.6                  | 689               |
| 2.4 (4 true-<br>leaf)                  | 95.4                   | 68.5                  | 287               | 66.3                   | 34.3                  | 505               | 59.3                   | 26.0                  | 669               |
| 3.1 (early<br>bud)                     | 97.0                   | 66.2                  | 266               | 65.5                   | 34.8                  | 483               | 54.0                   | 23.3                  | 643               |
| 4.1 (early<br>flower)                  | 95.0                   | 72.2                  | 226               | 69.9                   | 39.3                  | 433               | 57.2                   | 26.0                  | 612               |

\*Disease severity determined by categorizing plants as follows: 0 = No lesions on stem; 1 = Lesions on one side of the stem; 2 = More than 1/2 of stem circumference girdled by lesions; 3 = More than 1/2 of stem girdled, plant prematurely ripened but seeds healthy; 4 = Plant prematurely ripened and pods shrunken. Disease severity of plot = [(% 0 plants) + (2 x % 2 plants) + (3 x % 3 plants) + (4 x % 4 plants)]/4.



Appendix L. Pesticide Research Reports on 1988 experiments on foliar fungicide application to control blackleg.

- L - Report by K. Xi and R.A.A. Morrall (1988 a)
- L (i) - Report by K. Xi and R.A.A. Morrall (1988 b)

## Appendix L

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**CROP:** Canola, cvs. DN 188, Westar and Tobin**PEST:** Blackleg, *Leptosphaeria maculans***TITLE:** EVALUATION OF SINGLE, DUAL AND MULTIPLE APPLICATIONS OF FOLIAR FUNGICIDES AGAINST BLACKLEG OF CANOLA, 1988.**MATERIALS:** SPORTAK 400 g ai/h (prochloraz)  
TILT 250 g ai/L (propiconazole)

**METHODS:** The experiment was conducted at three locations in Saskatchewan as a split-plot 2 x 4 factorial with 4 replicates. The main plot effect was fungicide and the subplot effect was number of applications (0, 1, 2 or multiple). At Saskatoon plots were seeded with a small-plot tractor-drawn seeder on May 16 on land with infested canola residues from 1986 to act as natural inoculum. Each sub-plot was 8 rows, 4.6 m long and with 18 cm row spacing. The plots were irrigated at about 1-week intervals from seeding to harvest. At the other locations plots 6 x 2.5 m were marked out in commercial fields where short crop rotations led us to expect severe disease. A different cultivar was used at each location (see Table).

The single and dual applications were made when the plants were in the rosette stage, but spraying continued until early August in the multiple application treatment (see Table). The crop growth stages on the dates of spraying were not identical at each location. The fungicides were applied with hand-held sprayers using 80067 T-jet nozzles, 276 kPa pressure and the same dose of chemical and volume of water for each application. At Saskatoon the fungicides were applied in 390 l water/ha and at the other locations in 255 l water/ha.

Disease was assessed at maturity (August 8 - N. Battleford; August 18 - Maymont; August 20 - Saskatoon). About 75 plants were removed from the centre of each plot and disease incidence (DI) (% diseased plants) was determined. At N. Battleford and Maymont disease severity (DS) was also determined by categorizing each plant according to the extent of blackleg stem lesions (see Table). At Maymont the plants were sampled from a 1 m<sup>2</sup> quadrat and were also used to assess yield.

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Separate ANOVA were conducted on data from each location. The arcsin transformation was applied to DI data before analysis. Where appropriate specific contrast comparisons were made.

**RESULTS:** See Table. DI was low at Saskatoon on cv. DN 188 and there were no significant effects of the treatments. At North Battleford on the highly susceptible cultivar Westar DI was almost 100% in all plots, although there were significant effects of number of applications and in the contrasts check vs. sprayed and one vs. two applications. The same applied at Maymont, where DI was intermediate between the other locations. At both N. Battleford and Maymont there were no significant effects of fungicide on DI or in the interaction term. DS was significantly affected by number of applications at both N. Battleford and Maymont, by fungicide at Maymont only and by the interaction term at N. Battleford only. However, the effect at Maymont was probably artificial since even the check plots were consistently higher for one fungicide than the other. Overall prochloraz was slightly more effective than propiconazole. At both locations the contrast check vs. sprayed was significant and at N. Battleford the contrast one vs. two applications was significant. There were no effects of treatments on yield at Maymont.

**CONCLUSIONS:** The results were not consistent among locations, perhaps due to cultivar and weather conditions. The largest significant reductions in disease compared with the relevant check were about 30%, even though 5 or 6 fungicide applications had been made. At North Battleford where disease was severe, control, although limited, appeared to increase with number of applications. At Maymont multiple applications gave no better results than one or two early-season sprays. The results suggest that any further work with these fungicides should be integrated with methods of preventing infection very early in the season.

Effect of fungicides on blackleg disease\* in three cultivars at three locations

| Treatment*    | Fungicide     | Total dose<br>(g. ai/ha) | Saskatoon<br>(DN188) | N. Battleford (Westar) |                    | Maymont (Tobin)     |                    | Yield<br>(g/plot) |
|---------------|---------------|--------------------------|----------------------|------------------------|--------------------|---------------------|--------------------|-------------------|
|               |               |                          | % Disease Incidence  | % Disease Incidence    | % Disease Severity | % Disease Incidence | % Disease Severity |                   |
| Check         | -             | 0                        | 28.3                 | 99.8                   | 69.1               | 37.2                | 16.2               | 165               |
| 1st date only | Prochloraz    | 400                      | 24.8                 | 99.9                   | 60.5               | 30.7                | 13.3               | 135               |
| 1st 2 dates   | Prochloraz    | 800                      | 26.0                 | 97.9                   | 57.1               | 16.9                | 7.0                | 169               |
| All dates     | Prochloraz    | >2000                    | 27.2                 | 96.5                   | 49.5               | 20.3                | 9.6                | 170               |
| Check         | -             | 0                        | 29.8                 | 100                    | 67.4               | 55.8                | 27.0               | 120               |
| 1st date only | Propiconazole | 125                      | 28.0                 | 99.5                   | 70.2               | 37.8                | 16.2               | 156               |
| 1st 2 dates   | Propiconazole | 250                      | 27.3                 | 99.3                   | 66.2               | 43.9                | 20.9               | 131               |
| All dates     | Propiconazole | >625                     | 28.8                 | 99.5                   | 59.2               | 34.3                | 15.1               | 163               |

\*Disease severity determined by categorizing plants as follows: 0 = No lesions on stem; 1 = Lesions on one side of the stem; 2 = More than 1/2 of stem circumference girdled by lesions; 3 = More than 1/2 of stem girdled, plant prematurely ripened but seeds healthy; 4 = Plant prematurely ripened and pods shrunken. Disease severity of plot = [(% #1 plants) + (2 x % #2 plants) + (3 x % #3 plants) + (4 x % #4 plants)] / 4.

\*Plant growth stages and (dates of application) Saskatoon - 2.4 (June 13); 2.5 (June 21); 3.2 (June 30); 4.4 (July 10); 5.1 (July 20); 5.2 (July 29); N. Battleford - 2.4 (June 9); 2.5 (June 17); 3.1 (June 23); 4.2 (July 4); 5.1 (July 14); 5.3 (July 25); Maymont - 2.2 (June 25); 2.6 (July 4); 4.2 (July 14); 4.4 (July 25); 5.2 (August 3).

**CROP:** Canola, cvs. Westar and Tobin

**PEST:** Blackleg, *Leptosphaeria maculans*

**TITLE:** EVALUATION OF EARLY-SEASON APPLICATIONS OF FOLIAR FUNGICIDES AGAINST BLACKLEG OF CANOLA, 1988.

**MATERIALS:** BAY HMG 1608 2.5 FS, BAYLETON 50WP (triadimefon), ICIA0450 125 g/L SC (flutriafol), ROVRAL 25F (iprodione), SPOTLESS 25 WP (diniconazole).

**METHODS:** The experiment was conducted at two locations in Saskatchewan and involved 4 replicates and six treatments in an RCBD. Plots 6 m x 2.5 m were marked out in early June in commercial canola fields where short crop rotations led us to expect severe disease. At North Battleford a crop of cv. Westar and at Maymont a crop of cv. Tobin were used.

The plots received a single application of the fungicides at an early growth stage. At N. Battleford they were sprayed on June 9 when in Growth Stage 2.4 and at Maymont on June 25 when in Growth Stage 2.2. The fungicides were applied with an R and D Model G.3 hand-held sprayer using 80067 T-jet nozzles and 276 kPa pressure. All fungicides were applied in 255 l water/ha and at the doses shown in the Table.

Disease was assessed at plant maturity i.e. on August 8 at N. Battleford and on August 18 at Maymont. About 75 plants from the centre of each plot were used to determine disease incidence and disease severity by categorizing each plant according to the extent of blackleg stem lesions (see Table). Separate ANOVA were conducted on data from each location. The arcsin transformation was applied to disease incidence data before analysis.

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**RESULTS:** See Table. No significant differences among treatments were found for either disease incidence or disease severity at either location. However, flutriafol gave consistently the lowest values.

**CONCLUSIONS:** Under the conditions of this experiment the five fungicides were not effective in controlling the disease through a single foliar application. The values for disease severity expressed as a percentage of the non-treated check ranged from 89% to 98% at North Battleford and from 71% to 109% at Maymont. In another experiment conducted in adjacent plots at the same locations (Xi, K. and R.A.A. Morrall. Evaluation of single, dual and multiple applications of foliar fungicides against blackleg of canola, 1988. Pesticide Research Report, this issue), corresponding values for single applications of two other fungicides were: SPOTAK 87% at North Battleford and 82% at Maymont; TILT 104% at North Battleford and 60% at Maymont.

Effect of fungicides on blackleg disease\* at two locations

| Fungicide    | Dose<br>(g a.i./ha) | Location and Cultivar  |                    |                     |                    |
|--------------|---------------------|------------------------|--------------------|---------------------|--------------------|
|              |                     | N. Battleford (Westar) |                    | Maymont (Tobin)     |                    |
|              |                     | % Disease Incidence    | % Disease Severity | % Disease Incidence | % Disease Severity |
| Check        | -                   | 99.9                   | 69.2               | 42.8                | 18.0               |
| BAY HMG 1608 | 125                 | 99.6                   | 67.5               | 31.8                | 15.1               |
| BAYLETON     | 250                 | 99.3                   | 65.7               | 41.6                | 19.6               |
| ICIA0450     | 250                 | 99.0                   | 61.8               | 27.9                | 12.8               |
| ROVRAL       | 750                 | 99.9                   | 67.1               | 30.3                | 13.3               |
| SPOTLESS     | 100                 | 99.9                   | 63.6               | 31.8                | 13.1               |

\*Disease severity determined by categorizing plants as follows: 0 = No lesions on stem; 1 = Lesions on one side of the stem; 2 = More than 1/2 of stem circumference girdled by lesions; 3 = More than 1/2 of stem girdled, plant prematurely ripened but seeds healthy; 4 = Plant prematurely ripened and pods shrunken. Disease severity of plot = [(% #1 plants) + (2 x % #2 plants) + (3 x % #3 plants) + (4 x % #4 plants)] / 4.

Appendix M. Pesticide Research Report on 1988 experiment with flutriafol as a seed treatment and fertilizer coating.

CROP: Canola, cv. DN 188

PEST: Blackleg, *Leptosphaeria maculans*

TITLE: EVALUATION OF FLUTRIAFOL AS A SEED TREATMENT AND FERTILIZER COATING AGAINST BLACKLEG OF CANOLA, 1988.

MATERIALS: ICTA0450 (flutriafol). 11/51/0 and 34/0/0 fertilizers coated with flutriafol. 2.5 WP formulation for seed treatment.

METHODS: The fertilizers were coated with flutriafol by the manufacturer at two rates in each case: 0.5 and 0.75 g a.i./kg 34/0/0 and 1.8 and 3.0 g a.i./kg 11/51/0. Seed was treated with the 2.5 WP formulation about 3 days before planting in batches of about 200 g to give either 0.05 g or 0.10 g a.i./kg seed. Eight of the experimental treatments were in a 2 x 2 factorial x 2 nested arrangement (see Table). Seed treatment and fertilizer coating were mutually exclusive factors each tested at two levels on two fertilizers. In addition, three checks were included, one non-treated, one with non-coated 11/51/0 and non-treated seed, and one with non-coated 34/0/0 and non-treated seed. The fertilizers were used at 42 kg product/ha for 11/51/0 and 147 kg product/ha for 34/0/0 in order to give flutriafol doses of about 75 and 120 g a.i./ha with the two rates, respectively. The 34/0/0 was broadcast and incorporated into the soil before seeding, while the 11/51/0 was drilled with the seed. The plots were seeded at Saskatoon on May 16 on land with infested canola residues from 1986 to act as natural inoculum. The treatments were arranged in a 4-replicate RCBD. Seeding was done with a small-plot tractor-drawn seeder. Each plot was 16 rows, 4.6 m long with 18 cm row spacing. The plots were irrigated at about 1-week intervals from seeding to harvest.

The plots were harvested on August 25 by removing 80 plants from 3 rows towards one side of the plot and categorizing them according to the extent of blackleg stem lesions. The frequency of plants in each category was used to calculate percentage disease severity per plot (see Table).

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Two-way ANOVA was performed on disease incidence (% diseased plants) values after arcsin transformation and on disease severity values. Where appropriate, specific contrast comparisons of individual factors were made.

RESULTS: Specific contrasts showed that in the absence of flutriafol the fertilizers significantly increased disease incidence and severity ( $p=0.05$ ), but that the fungicide significantly reduced disease ( $p=0.01$ ). Flutriafol was significantly better in combination with 11/51/0 than in combination with 34/0/0 in reducing disease incidence ( $p=0.05$ ), but not in reducing disease severity. Seed treatment with no fertilizer coating gave significantly lower disease incidence values ( $p=0.05$ ) than fertilizer coating without seed treatment, but not lower disease severity values. There were no significant interactions between fertilizer coating vs non-coating and type of fertilizer. Finally no significant effects of rate of fungicide application occurred with either fungicide or either method of application.

CONCLUSIONS: The greatest reduction in disease severity relative to the pertinent check with fertilizer was 35.5% (mean of 2 rates) with seed treatment and non-coated 11/51/0. It will be necessary to conduct additional experiments to determine whether such a reduction would economically justify seed treatment with flutriafol. Moreover, further work is needed to determine if reductions in disease from seed treatment and fertilizer coating such as observed in this experiment might be additive in nature.

Effect of flutriafol and fertilizers on blackleg disease in canola

| Fertilizer                                | 0    | 11/51/0 | 34/0/0 | 11/51/0                             |                  |                                     |                | 34/0/0                              |                  |                                     |                |
|-------------------------------------------|------|---------|--------|-------------------------------------|------------------|-------------------------------------|----------------|-------------------------------------|------------------|-------------------------------------|----------------|
| Coating or seed treatment with flutriafol | 0    | 0       | 0      | Fertilizer coated: Seed non-treated |                  | Fertilizer non-coated: seed treated |                | Fertilizer coated: Seed non-treated |                  | Fertilizer non-coated: seed treated |                |
| Flutriafol dose                           | 0    | 0       | 0      | 1.8 g/kg 11/51/0                    | 3.0 g/kg 11/51/0 | 0.05 g/kg seed                      | 0.10 g/kg seed | 0.5 g/kg 34/0/0                     | 0.75 g/kg 34/0/0 | 0.05 g/kg seed                      | 0.10 g/kg seed |
| % Disease incidence                       | 34.3 | 42.3    | 51.0   | 37.1                                | 30.8             | 29.0                                | 30.1           | 38.4                                | 45.9             | 33.4                                | 34.3           |
| % Disease severity*                       | 19.6 | 25.2    | 26.2   | 21.8                                | 16.5             | 16.5                                | 15.9           | 19.6                                | 22.1             | 16.2                                | 20.1           |

\*Disease severity determined by categorizing plants as follows: 0 = No lesions on stem; 1 = Lesions on one side of the stem; 2 = More than 1/2 of stem circumference girdled by lesions; 3 = More than 1/2 of stem girdled, plant prematurely ripened but seeds healthy; 4 = Plant prematurely ripened pods shrunken. Disease severity of plot = ((% #1 plants) + (2 x % #2 plants) + (3 x % #3 plants) + (4 x % #4 plants))/4.



Appendix N. Reports from blackleg disease nurseries, 1986-88.

- N - Brassica napus, 1986
- N (i) - Brassica campestris, 1986
- N (ii) - Brassica napus, 1987
- N (iii) - Brassica campestris, 1987
- N (iv) - Brassica campestris, and B. napus, 1988.

1986 Blackleg Nursery (B. napus)Location: MelfortDate of seeding: May 21Infection: Natural from 1984 infected rape residues on the land, plus 1985 residues distributed on surface, June 10.Irrigation: NonePlot size: 6 rows, 5 m long, 18 cm row spacingReplicates: 4Rate of seeding: As for rape co-op.Conditions: Very dry from seeding to mid-July. Substantial frost damage on June 13. Adequate moisture from mid-July to early August. However, plants severely stunted and stand lightDisease Rating: August 21-22. 100 plants removed from centre 2 rows of each plot, rated on a scale of 1 (clean) to 5 (severely diseased). Percentage disease rating calculated.

| <u>Entry</u> | <u>Mean Disease Rating</u> |
|--------------|----------------------------|
| Vestar       | 42.8 a *                   |
| ZN80-1280    | 40.0 ab                    |
| 31-17016A    | 39.3 ab                    |
| VBC7         | 34.8 abc                   |
| Andor        | 32.8 bc                    |
| Tribute      | 30.8 bcd                   |
| Triton       | 29.8 cd                    |
| Regent       | 26.8 cde                   |
| Midas        | 22.8 def                   |
| SV02404      | 17.8 efg                   |
| S81-2716     | 17.8 efg                   |
| SV02402      | 16.5 fg                    |
| DN-188       | 15.8 fg                    |
| DO-195       | 13.3 fg                    |
| S82-4362     | 13.3 fg                    |
| S82-1603     | 11.0 gh                    |
| R83-11       | 9.8 gh                     |
| AV001        | 8.0 gh                     |
| Global       | 1.8 h                      |

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|                              |       |
|------------------------------|-------|
| F ratio in ANOVA (18, 54 df) | 16.11 |
|------------------------------|-------|

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\*Values in column followed by same letter not significantly different at  $p=0.05$  according to Duncan's multiple range test.

1986 Blackleg Nursery (B. campestris)Location: MelfortDate of seeding: May 22Infection: Natural from 1984 infested rape residues on the land.Irrigation: NonePlot size: 6 rows, 5 m long, 18 cm row spacingReplicates: 4Rate of seeding: As for rape co-opConditions: Very dry from seeding to mid July. Adequate moisture from mid-July to early August. However, plants stunted and stand light.

Disease Rating: August 21. Only 3 replicates rated. 100 plants removed from centre 2 rows of each plot, rated on a scale of 1 (clean) to 5 (severely diseased). Percentage disease rating calculated. NOT The plants were overripe at the time of rating and difficult to assess. It is probable that most of the symptoms observed were derived from infection by the weakly virulent strain of blackleg. Little disease was observed on the plants earlier in the season.

EntryMean Disease Rating

|           |      |
|-----------|------|
| BL-GHY-1  | 30.7 |
| BL-802-2A | 30.3 |
| Tobin     | 29.0 |
| SV03333   | 27.3 |
| Candle    | 25.0 |
| SV03334   | 22.3 |
| SV8236579 | 20.7 |
| SV8236627 | 20.3 |

F ratio in ANOVA (7, 23 df)

1.96 NS

1987 Supplementary Blackleg Nursery (B. napus)

R. Morrall

Location: MelfortDate of seeding: May 25Infection: Natural inoculum from 1984 infected rapeseed residues on the land. No artificial irrigation.Replicates: 4Plot size: 3 rows, 5 m long,  
18 cm row spacingRate of Seeding: As for rapeseed co-opConditions: Very dry from seeding to mid-July, but above average moisture subsequently. However, plants were severely stunted and the stand was light. Infestation with shepherd's purse was considerable. Disease development was limited and variability among replicates was considerable.Disease rating: August 19. 100 plants were removed from each entry and rated on a scale of 1 (clean) to 5 (severely diseased). Percentage disease rating then calculated.

| <u>Entry</u> | <u>Code</u> | <u>Mean Disease Rating</u> |          |
|--------------|-------------|----------------------------|----------|
| 563787       | N 87-4      | 20.8                       | a*       |
| VBC-7        | N 87-5      | 20.8                       | a        |
| C 62387      | N 87-10     | 17.8                       | ab       |
| Vestar       | Vestar      | 16.3                       | abc      |
| ZN 84-1878   | N 87-16     | 15.8                       | abc      |
| LD 9922      | N 87-3      | 14.8                       | abc      |
| Altex        | Altex       | 12.3                       | bcd      |
| 83-52801B    | N 87-8      | 11.5                       | bcd      |
| 83-52808B    | N 87-17     | 11.0                       | bcd      |
| Midas        | Midas       | 10.3                       | bcde     |
| Tribute      | Tribute     | 10.0                       | bcde     |
| Regent       | Regent      | 9.3                        | cdef     |
| CS002        | N 87-14     | 8.8                        | cdef     |
| SV02404      | N 87-11     | 5.3                        | def      |
| SV02402      | N 87-7      | 5.3                        | def      |
| DN 188       | N 87-13     | 5.0                        | def      |
| AU 008       | N 87-9      | 5.0                        | def      |
| S83-1553     | N 87-12     | 4.8                        | def      |
| CS 001       | N 87-6      | 4.8                        | def      |
| AU 001       | N 87-1      | 2.5                        | ef       |
| S82-4362     | N 87-2      | 2.5                        | ef       |
| AU 022       | N 87-15     | 1.5                        | f        |
| Mean         |             | 9.7                        | CV = 51% |

\*Values followed by same letter not significantly different at  $p = 0.05$  according to Duncan's multiple range test.

1987 Supplementary blackleg nursery (B. campestris)

R. Morrall

Location: MelfortDate of seeding: May 25Infection: Natural inoculum from 1984 infected rapeseed residues on the land. No artificial irrigation.Replicates: 4Plot size: 3 rows, 5 m long,  
18 cm row spacingRate of Seeding: As for rapeseed co-opConditions: Very dry from seeding to mid-July, but above average moisture subsequently. However, plants were severely stunted and the stand was light. Infestation with shepherd's purse was considerable. Disease development was limited.Disease rating: August 11. 100 plants were removed from each entry and rated on a scale of 1 (clean) to 5 (severely diseased). Percentage disease rating then calculated.

| <u>Entry</u> | <u>Code</u> | <u>Mean Disease Rating</u> |          |
|--------------|-------------|----------------------------|----------|
| 83-51249N    | C87-3       | 32.5                       | a*       |
| SV03334      | C 87-6      | 31.3                       | a        |
| Tobin        | Tobin       | 29.8                       | ab       |
| 83-51243N    | C 87-9      | 29.3                       | ab       |
| SV03333      | C 87-1      | 28.3                       | ab       |
| SV8236579    | C 87-8      | 28.0                       | ab       |
| S83-5009     | C 87-5      | 26.3                       | abc      |
| S83-4302     | C 87-2      | 24.0                       | bcd      |
| ACS-C2       | C 87-7      | 23.0                       | bcd      |
| 83-52692B    | N 87-20     | 21.0                       | cd       |
| ACS-C1       | C 87-4      | 19.0                       | de       |
| C 56687      | N 87-18     | 14.5                       | e        |
| AU 028       | N 87-19     | 7.3                        | f        |
| Mean         |             | 24.2                       | CV = 17% |

\*Values followed by same letter not significantly different at  $p = 0.05$  according to Duncan's multiple range test.



1988 Blackleg Nurseries (Co-op A test)

R.A.A. Morrall

Location: Melfort      Date of seeding: May 19

Infection: Natural inoculum from 1987 infested residues on adjacent land plus distribution of infested 1987 residues in plots on June 25. No artificial irrigation.

Replicates: 4-RCBD      Plot size: 3 rows, 5m long, 18cm row spacing

Rate of seeding: As for rapeseed co-op.

Conditions: Very dry from seeding until early July and below normal moisture subsequently. Germination was poor and weed growth was very limited. Consequently plant population was very low, but plants were very robust. Disease development was very limited.

Results: *B. campestris* nursery was abandoned after a preliminary rating of two replicates on August 9, as most disease ratings were very low (i.e. between 5 and 10%).

Disease ratings were also low in the *B. napus* nursery. Consequently, only 11 selected entries were rated for disease. Rating was done by removing 50 plants from each plot and rating each plant on a scale of 0 (clean) to 5 (severely diseased). Percentage disease ratings per plot were then calculated.

B. napus entryMean disease rating

|          |                 |
|----------|-----------------|
| Westar   | 15.0 a*         |
| ACS-N4   | 12.4 ab         |
| Regent   | 12.3 ab         |
| SVO 2404 | 10.0 ab         |
| CS 002   | 9.5 ab          |
| ACS-N3   | 9.0 abc         |
| SVO 2402 | 8.8 abc         |
| DO 195   | 7.3 bc          |
| DN 188   | 6.9 bc          |
| ACS-N1   | 6.6 bc          |
| Global   | 1.8 c           |
| <hr/>    |                 |
| Mean     | 9.0      CV=50% |

\*Means followed by same letter not significantly different at  $p=0.05$  according to Duncan's multiple range test.